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ORANGES AND SNOW IN CALIFORNIA.

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CITRUS PRODUCTS

PART II

BY

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CHAPTER XI

ECONOMICS OF THE CITRUS PRODUCT INDUSTRY

CITRUS FRUIT PRODUCTION

The most important of the citrus fruits from the standpoint of the citrus products industry is the lemon. As may be seen from the table below, Italy is by far the largest grower and exporter of lemons. At the same time this country is also the principal source of lemon oil, citrate of lime, and citric acid.

TABLE XXIX

LEMONS—INTERNATIONAL TRADE, 1913, 1921–23*

(Boxes of 84 lbs., expressed in 1,000)

Country	1913		1921		1922		1923	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Austria	1,519	218	.....	.....	.....	.....	.....	.....
Germany	965	†	972	†	571	†	341	†
United Kingdom†	896‖	.....	1,072	.....	1,160	.....	1,250	.....
Netherlands	75	4	151	23	136	11	139	10
Denmark	23	.....	27	.....	28	.....	28	.....
Sweden	22	.....	26	.....	28	.....	28	.....
Italy	1	8,005	1	4,155	‡	3,567	1	3,699
Spain	.....	87	.....	240	‡	157	‡¶	89¶
United States	§	58	§	304	1,321	174	1,499	182
Cuba	.....	3	.....	.....	.....	.....	.....	.....

*Compiled from official sources except where otherwise noted.
† Not separately stated.
‡ Less than 500 boxes.
§ Expressed in value only.
‖Includes limes and grapefruit.
¶Ten months ending October 31.

BASIC FACTS RELATING TO THE CALIFORNIA PRODUCTS INDUSTRY

In normal years 10 per cent of the lemon crop and 3 per cent of the orange crop is classed as "culls" and are not fit for shipment because of their physical condition.[1] Under unfavorable conditions as much as 40 per cent of the fruit may be classed as "culls," since it cannot be sold for enough to pay the cost of harvesting, shipping, and selling. It must, however, be harvested and sorted out in the packing-house and the expense involved in this handling is a loss to the grower unless the fruit can be converted into products which will sell at a price that will at least cover these costs.

[1]For a more complete definition of "culls" see p. 4.

The conversion of this waste fruit in the United States into a useful product is necessary to the stability of the fruit growing industry.

THE LEMON PRODUCTS INDUSTRY IN ITALY[1]

In Italy, the principal country producing lemons outside of the United States, where the cultural conditions result in a higher proportion of unsalable fruit, from 30 to 50 per cent of the total crop of lemons is converted into citrate of lime, citric acid, and lemon oil. In order to aid the prosperity of the lemon industry, the Italian government has created a by-products monopoly through which it is sought to guarantee a fair price to the grower and to control and regulate the market for these products.

The United States Tariff Commission has made an investigation of the by-products business in Italy. It has the following to report about its control by the Italian government:

> An important feature of the industry is the Sicilian method of selling the citrus products. The Italian Government created a citrus chamber of Camera Agrumaria, to control and regulate the market for citrus products. This Chamber is made up of a certain number of producers and exporters from each of the Provinces together with representatives from the ministries of commerce and agriculture and a president nominated by the council of ministers.
>
> Citrate of lime and citric acid are handled almost exclusively by the Camera which fixes the prices periodically and through its agents allots monthly deliveries to buyers all over the world. It guarantees the producer a certain minimum price for his product and the Italian Government levies an export duty amounting to 1 lire per quintal (0.087 cent per pound) on all sales not made through the Camera Agrumaria. The producers deposit their output with the Camera and they are advanced 80 per cent of the value of the citrate of lime, and the balance is adjusted when the sale is made.[2]

Citric acid, citrate of lime, and lemon and orange oils are articles of the world-trade. The United States offers the largest available market for them. Citric acid is imported into the United States chiefly in the form of citrate of lime and is here converted into citric acid, though in the last few years large quantities of citric acid have been imported as such. A large amount of citric acid is also imported in the form of concentrated lemon or lime juice, which, under the previous tariff, was admitted duty-free.

FUTURE OF THE AMERICAN CITRUS PRODUCTS INDUSTRY

The American lemon industry is growing rapidly. California will produce 5,000,000 boxes in excess of the total normal consumption of lemons in the United States. There are 17,000 acres of non-bearing

[1] See pp. 336, 337, 349, 355, 360, 361–68 for additional statistics.

[2] *Tariff Information Series No. 13* (1920), p. 24.

lemon trees in California, which, if the industry is maintained, will increase this surplus in the next few years to at least 3,000,000 boxes.[1] This increase in production will increase the supply of cull lemons which furnish the raw material for citrus products.

California is now producing one-third of the citric acid used in the United States and will largely increase its production in the next few years. Five factories, two of which are operated by co-operative growers' organizations, have already been established to handle orange and lemon by-products. These factories are prepared to utilize the entire cull supply if the tariff makes continued operation and the expansion of the industry possible.

The United States Tariff Commission has the following to say about the domestic citrus products industry and its future:

> There is an opportunity for the growth of the citrus by-products industry in California through the more complete utilization of the culls and through the growth of the lemon-growing industry. The acreage of young, non-bearing lemon groves in California is about 75 per cent of the acreage of bearing trees, and much of the latter is in young orchards which have not reached the full-bearing stage. It may, therefore, be predicted that within five or six years the total crop of lemons will be nearly double that produced during 1918. If the same proportion of the crop were treated as culls, and if all the culls were converted into useful products, the production of these would be about four times as great as at present [1918]. Should it prove difficult to sell the double crop of lemons at profitable figures, the tendency will be to grade more strictly, and thereby to increase the proportion of culls.[2]

THE COST PER TON OF HANDLING CULL LEMONS IN THE UNITED STATES

The cost of converting cull lemons into citric acid and lemon oil in California is known from the records of the Exchange Lemon Products

TABLE XXX

COST OF HANDLING AND PROCESSING LOW-GRADE LEMONS

	Cost per Ton	Percentage Labor	Labor Cost per Ton
Gathering fruit	$ 9.00	95	$ 8.55
Transportation to central factory	5.79	60	3.47
Factory operation and maintenance	14.73	30	4.42
Total	$29.52	.....	$16.44

[1] See diagram, pp. 1, 2.

[2] *Tariff Information Series No. 13* (1920), p. 26.

Co. and the United Chemical Works, which have converted 70,000 tons of lemons into these products since 1916. The present cost of harvesting the fruit, handling it to the central factory and of manufacturing, including the proportion of the cost represented by labor, is set forth in Table XXX.

Since both citric acid and oil of lemon are manufactured from the lemons, a proper division of the labor costs per ton as outlined in Table XXX is estimated to be $14.24 for 40 lb. of acid and $2.20 for 5 lb. of lemon oil produced from one ton of cull fruit. This represents 35.6 cents per pound of citric acid and 44 cents per pound of lemon oil.

All citric acid in the course of its manufacture passes through the citrate of lime stage. The labor required to convert this into citric acid costs approximately 4 cents per pound of acid crystallized. The labor cost of acid in the citrate stage is therefore 31.6 cents per pound. A pound of citrate contains 64/100ths pound of pure acid, the labor cost of the acid as represented in this citrate of lime stage is therefore 20.2 cents per pound.

COMPARATIVE LABOR COSTS OF HANDLING CULL LEMONS AND OF MANUFACTURING BY-PRODUCTS IN THE UNITED STATES AND ITALY

Using the cost of labor on citric acid made in California as outlined above at 35.6 cents per pound, the comparative labor cost of Italian citric acid is 8.9 cents per pound, the labor ratio between the United States and Italy being 4 to 1.

TABLE XXXI

COMPARATIVE WAGES* IN ITALY AND AMERICA

Class of Labor	Italian Wage	American Wage	Ratio
Fruit gathering	$0.52 to $0.62	$2.50 to $3.00	1:48
Rough labor	.69 to .78	2.75 to 3.25	1:4
Process men	.87 to .90	3.20 to 3.60	1:38
Chemists and mechanics	.93 to .95	3.60 to 4.80	1:44
General average ratio, taken as			1:4

* The Italian wages are taken from tables compiled by the clerk of the Ways and Means Committee (*Tariff Information Series* (1921), "Wages in the United States and Foreign Countries" (pp. 9, 36). The wages in California are taken from the records of those handling cull lemons and manufacturing these products.

The comparison of wages, including the ratio between the Italian and American rates, is set forth in Table XXXI. The comparative domestic and foreign labor costs applied to citrate of lime are, respectively, 20.2

cents and 5.1 cents per pound. The comparative labor costs of domestic and Italian oils are 44 cents and 11 cents per pound. The difference in labor costs in favor of Italy is 26.7 cents on citric acid, 15.1 cents per pound on citrate of lime, and 33 cents per pound on oil. The value of imported oil is approximately 80 cents per pound or 72 cents before payment of duty. An ad valorem rate of 40 per cent equal 28.8 cents per pound, or 4.2 cents per pound less than the difference in labor cost in favor of Italy.

TABLE XXXII

COMPARATIVE COST OF LABOR PER POUND OF CITRIC ACID, CITRATE OF LIME, AND LEMON OIL IN THE UNITED STATES AND ITALY

	United States (Cents)	Cost of Labor per Lb. in Italy (Cents)	Difference in Favor of Italy (Cents)
Citric acid.....	35.6	8.9	26.7
Citrate of lime.....	20.2	5.1	15.1
Lemon oil.....	44.0	11.0	33.0

Table XXXII shows a comparison of the cost of labor per pound of citric acid, citrate of lime, and lemon oil in the United States and Italy and the difference in favor of Italy.

SUMMARY

The manufacture of commercial products from orange and lemon culls is a new industry in the United States as indeed is the entire citrus products industry.

The effective salvage of unsalable fruit through the manufacture of by-products would appear to be a desirable aid to the stability of the citrus industry.

The lemon by-products industry in Italy, America's principal competitor, is controlled by a government monopoly of long standing which provides for the disposal of 30 per cent to 50 per cent of the Italian crop.

Factories now operating in California can supply one-third of the citric acid consumed in the United States; their output is likely to be greatly increased if adequate tariff protection is afforded them.

The rapid expansion of the citrus growing industry, particularly in the production of lemons, the supply of which already exceeds the normal domestic consumption, will provide an increasing volume of fruit to be employed in citrus products manufacture.

The prevailing wage in the United States scale is four times that of Italy.

Excess of American labor cost over Italian labor cost is known to be: 26.7 per pound of citric acid produced; 15.1 cents per pound of citrate of lime produced; 33 cents per pound of oil of lemon produced.

LIMES AND LEMONS AS SOURCES OF CITRIC ACID AND ESSENTIAL OILS

During recent years, in tropical agriculture, lime cultivation has been one of the minor booms. Prices have ruled extraordinarily high for the various citrus products, and at the present time large areas of land are being placed under cultivation not only in the West Indies but also in other parts of the tropics.

For the present there are no indications that the supply of lime products will exceed the demand. As a matter of fact, the demand for limes is sufficiently distinct from that for lemons, so that there is but little overlapping, but the fact remains that Sicily with her lemon production to a large extent regulates the market price for citric acid, which is the essential constituent of lime juice and of calcium citrate. Sicily, also, because of her large production, influences the prices for all the essential oils of the citrus group.

It occurred to Dunlap, in view of the increasing area under limes and the attention which lime growers give to Sicilian affairs, that it would be interesting to contrast the lemon and the lime as sources of citrus products, to compare their respective yields, and their positions in the world's markets. At the same time it was thought desirable to give in outline the methods practiced in cultivating limes in the West Indies for the benefit of capital seeking investment, and to indicate how the market opinion of lime products compares with that of lemon products. The lemon is not, like the lime, dealt with from the agricultural standpoint, for the reason that the area under lemons—except perhaps in districts of the United States—cannot readily be extended, for the plant seems to require very special conditions of soil and climate, and the industry in Sicily is fully established. Moreover the lime crop appears to be better suited to tropical conditions than the lemon. As regards foreign countries, the future development of the citrus products manufacture will probably depend chiefly upon the extension of lime cultivation to which the West Indies and Central America are especially well adapted.

EXTENT OF PRODUCTION OF CITRUS PRODUCTS

The principal commodities dealt with in this book are raw and concentrated lime juice, citrate of lime, and the essential oils. Some idea

of the relative importance of lemon and lime products can be obtained from the following tables. The first one, Table XXXIII, shows the exports of lime products from the British West Indian Colonies[1] during 1913–14.

TABLE XXXIII

Dominica	£142,662
Montserrat	5,977
Jamaica (average last four years)	4,179
St. Lucia	3,108
British Guiana	1,530
Total	£175,456

These figures include the fresh limes exported chiefly to New York, worth about £40,000. It may be added that lime products worth some thousands of pounds are also exported from Porto Rico, Mexico, and other foreign countries of Central America.

The value of citrus products prepared from the lemons exported from Sicily in 1908, which may be taken as an average year, amounted to about £840,650. Bulletin No. 60, Bureau of Plant Industry, United States Department of Agriculture, gives the following analysis (Table XXXIV).

TABLE XXXIV

Citrate of lime	$2,678,489
Citrus essential oils	1,380,455
Raw juice	121,098
Concentrated juice	23,208
Total	$4,203,650*

*Approximately £840,650.

As a general rule, the value of the fresh lemons exported equals the combined value of the so-called by-products, excluding peel. This shows the magnitude of the citrus trade of Sicily. During 1912–13, the fresh fruit trade increased greatly owing to the failure of the California crop, which partly meets the American demand. Hence the amount of by-products that could be made in Sicily was relatively small, and consequently prices ruled high for the West Indian products. During 1912–13 the quantity of citrate of lime produced by Sicily was only 3,445 metric tons and of concentrated juice only 22,042 imperial gallons—considerably less than the mean annual production or consumption during the last five years.

It is thus evident that Sicily, being the chief source of citrus products, must to a large extent regulate the market: It may be remembered, how-

[1]See Appendix, pp. 354, 355, for later statistics on West Indian products.

ever, that the total or combined exports of lemons and by-products from Sicily has not increased for years and is not likely to grow appreciably larger. On the other hand the export of lime products has increased rapidly during the past few years and is certain to increase farther, strengthening the position of limes on the market.

COMPOSITION OF THE TWO FRUITS

The commercial yields of acid and oils will be described later. In this section attention will be given to the chemical composition of the fruits.

The *Lancet* for March 28, 1908, published the results of analyses of two samples of limes and lemons which showed the lime in all important respects to be the richer fruit. The report, which was reproduced as a leaflet by the West India Committee, stated that "the lime, although smaller than the lemon, yields, weight for weight, a good deal more juice. Thus the average amount of juice expressed from a lemon was 37.5 per cent of its weight, whereas the lime gave 59.0 per cent. Moreover the lime gives more citric acid but less sugar." This report included analyses, which showed the citric acid content of the lemon to be 4.57 and that of the lime 5.60 gm.

TABLE XXXV

	Description of Fruits	Number of Fruits to 500 gm.	Juice Expressed (Per Cent)	Citric Acid in Juice* (Grams per 100 c.c.)
A. Limes.....	Fully ripe, in fair condition and of good size.....	9½	56.8	7.05
B. Limes.....	Fully ripe, poor condition, of uniform size.....	15	47.0	7.74
C. Lemons.....	Three fully ripe and three slightly green, small.....	6	28.8	7.56
D. Lemons.....	Good quality and size.....	3¾	41.6	6.77
E. Lemons.....	Good quality and uniform, very small, almost approaching the lime.....	7½	40.8	7.4

*Expressed as crystallized citric acid, containing 1 molecule of water.

TABLE XXXVI

	Juice Expressed (Per Cent)	Citric Acid in Juice (Grams per 100 c.c.)
Limes.....	51.9	7.40
Lemons.....	37.1	7.24

In order to extend this investigation Dunlap secured two commercial samples of limes from different sources, and three commercial samples of lemons from ordinary retail shops in London. The results obtained on examination are in Table XXXV.

Taking the average of the figures shown in columns 4 and 5 of Table XXXV we get results given in Table XXXVI.

These results show, even with limes not of the first grade, that the lime undoubtedly contains a higher percentage of juice and of citric acid than the lemon, but the difference is not quite as great as the *Lancet* figures seem to show. Dr. Watts, in the West Indies, during 1905 tested limes and lemons grown in Dominica,[1] and as regards the acid content obtained the results in Tables XXXVII and XXXVIII.

TABLE XXXVII

LIMES

	Spineless	Ordinary
Percentage of juice	51.3	50.8
Citric acid, grams per 100 c.c.	11.70	11.15
Citric acid, ounces per gallon	15.71	14.18

TABLE XXXVIII

LEMONS

	Italian	Villa Franca
Citric acid, grams per 100 c.c.	11.17	11.37
Citric acid, ounces per gallon	13.28	15.39

These values relatively are more in accord with Dunlap's figures, though absolutely the acid content is much higher. It is clear that in the case of the relative composition of citrus fruits great care must be exercised to secure examples which are in a comparable condition. There is undoubtedly a loss in citric acid on keeping.

At all events Dunlap's figures are of interest as an indication of the composition of the limes and lemons that are sold during the winter months in London.

It would appear that the lemon contains a larger percentage of essential oils than the lime, possibly owing to the thickness of the skin. The lime is richer in phosphoric acid and possesses special anti-scorbutic properties—matters of importance from a dietetic point of view.

METHOD OF CULTIVATING LIMES

The cultivation of limes in the West Indies is fully treated in pamphlets of the Imperial Department of Agriculture for the West Indies, but it may be well to give an outline here of the methods adopted.

[1]See *Annual Report on Botanic Station*, Dominica, 1905–6.

Moreover, the principles governing the preparation of lime products are the same as for the lemon, so that the information will be of interest to the reader who is unfamiliar with one industry or the other.

Selection of land.—The establishment and general management is sketched for an estate in Dominica or St. Lucia, two of the principal citrus islands of the Lesser Antilles.

It is advised that flat or gently undulating lands should be chosen if possible, in a locality which is well sheltered and situated from sea-level up to 800 ft. elevation, and possessing a rainfall varying from 80 to 160 in. per annum. If the rainfall is well distributed, 60 in. may suffice. In the West Indies, where limes thrive best, the average temperature is about 80°F. in the shade.

Preparation of land and planting.—If necessary, the land is cleared of forest in the usual way, and after planting the seedlings (generally 15 ft. × 15 ft.) the weeds are kept down by cutlassing around the young plants. Before planting, however, adequate provision has to be made for roads, drainage, and windbreaks. Drainage depends upon local conditions of soil and climate, but often it is not apparent that drainage is necessary until the estate is being worked. Care should be taken to plant the trees in straight lines; otherwise, if drainage operations have to be started, grave damage may be done to the groves. Windbreaks are generally essential from the beginning. There are several trees used as permanent windbreaks, such as Galba (*Calophyllum Calaba*) and Pois-doux (*Inga laurina*); whilst the sugar-cane and Madura (*Glyricidia maculata*) make good temporary shelters.

Nursery work.—Seedlings for planting out are raised in special seed-beds in nurseries. Up to the present most of this work in the West Indies has been undertaken by the local agricultural departments, which have supplied the estate with many thousands annually. Now the estates are beginning to raise their own stock. There are no special difficulties attending this work, provided a good water supply is secured. Success then depends largely on practical experience.

After-cultivation and manuring.—The point to remember in this connection is that the root system of the lime tree is surface feeding. Hence tillage has to be very cautiously performed, and it is generally disadvantageous in the long run to plant catch crops. Very little pruning is required, but attention must be paid to cases of injury by wind and to replacing trees that die.

As regards manuring, the first essential is to maintain the soil humus. This is done by the careful use of green dressing and by the application of mulch, green manure, and possibly artificial manures. Very little is yet known concerning the manuring of limes. Experiments have been carried on in this direction at Dominica. As a matter of fact, there is not a great deal known about the requirements of the lime plant. It has been rather neglected, because it was not until quite recently that this plant became prominent in cultivation. More attention, experimentally, has been given to its products, like the composition of the fruit, lime juice, and oils.

Pests and diseases.—A considerable amount of work has, however, been done in connection with the pests and diseases of the lime tree, principally by

the entomologists and mycologists of the Imperial Department of Agriculture. The insect pests attacking limes have not as a general rule assumed a serious aspect. Fungus troubles have been greater, and the well-known local West Indian root disease occasions considerable loss in some places unless draining, trenching, liming, and the burning of diseased material is rigorously carried out.

Time of maturity and yields.—The lime crop takes about five years to come into bearing. Under favorable conditions the trees may yield a few fruits in the third year, but it is nearer eight or ten years before the estate can be regarded as yielding its maximum crop. A lime tree continues to yield for at least forty years after first beginning to bear.

In Dominica and St. Lucia the main crop is gathered from June or July to November or December. Four or six months are required for the development of the fruit from the flowering stage.

The yield per acre of an established lime plantation varies considerably, but a good average is 150 barrels of fruit. The weight of a barrel (4½ cu. ft. contents) of limes is about 160 lb. Hence an acre of good land may be regarded as yielding 24,000 lb. of fruit.

Harvesting.—The gathering of the crop depends upon the way it is to be disposed of. Fresh limes for export as such are picked from the trees in a green condition; fruit from which manufactured products are to be made is allowed to ripen on the tree and to fall to the ground.

Fresh limes.—During the last ten years a very considerable trade in fresh limes has developed between Dominica and New York. Latterly St. Lucia and other West Indian colonies have participated in this trade. Great care is exercised in the matter of preparing the fruit for export. The green fruit is kept in a packing-house for a few days previous to being shipped in order to allow the fruit to quail, or cure, that is, lose excess of moisture in the skins. The fruit must be carefully graded, wrapped in paper, and packed in ventilated packages.

Whether, in the future, as the area under limes grows larger, the fresh fruit trade will increase greatly, is difficult to foresee. In the United States the lime appears to be replacing the lemon for many purposes. In the case of the United Kingdom, the trade has never assumed any great importance for several reasons. In the first place the voyage to England is nearly twice as long as to New York, which puts difficulties in the way of the transportation of perishable produce. Secondly, the British taste is conservative. The public is familiar with the lemon, and is not generally inclined to discard it in favor of the lime, even if this fruit were regularly available. As a matter of fact, the fresh lime is available in quantity only during the latter half of the year, while the lemon is always to be had. Furthermore, the fresh lime is essentially an article for immediate sale. It does not keep as well as the lemon, and the retail salesmen do not view it with favor from a business point of view. In New

York, on the contrary, the consumption during the hot months is rapid and continuous; the fruit can be bought with a certainty of profitable sale.

The peculiar feature of the fresh lime trade is its elasticity or accommodating nature. If prices range beyond a certain point it pays to ship; if they do not, the fruit can be held back for manufacturing purposes. The trade with New York is conducted on this principle.

In the case of the United Kingdom it seems to the growers at present quite unnecessary to go to any expense for the purpose of increasing the fresh lime trade, since more profit is to be had there from concentrated juice and the essential oils.

THE PRODUCTION OF LEMON PRODUCTS IN SICILY

Lemon cultivation in Sicily and other parts of the subtropics has characteristic features. Variation in the physical condition of the soil affects the relative yields of juice and oil, not to mention the period of ripening. In a general way, also, irrigation and protection from frost are necessary for lemon cultivation, which differs from lime growing in these respects. Another matter of interest is that the plants are usually kept in the nurseries until three years old. They are then planted in the groves (generally 15 ft. × 15 ft.) and come into bearing when six years old.

The season of lemon ripening in Sicily varies. It is considered to begin on October 1 and end on September 30 following. Fruit is produced all the year round. The heaviest yields of each locality usually occur during the second, third, or fourth months in the season. The fruit gathered in the first harvest in each section is considered to be inferior in keeping quality.

Yields and profit.—On this point we may quote the *Perfumery and Essential Oil Record* for August, 1914, which contains a translation of an article that appeared during the same year in *Le Journal d'Agriculture Tropicale.*

Working on averages we get the following figures: 1,000 fruits of 100 grams, that is to say 100 kilograms give (after machine peeling to a depth of 2 mm., and thus removing the portion rich in essence) 30 kilograms of peel, from which by sponge or "écuelle" may be obtained 400 grams of essential oil. This yield varies with locality, care in cultivating, variety, and soil. It may be reckoned, then, that 2,500 fruits give a kilogram of essence, and, accepting the figure of 275,000 fruits per hectare, a total of 100 to 110 kilograms of essence for this area. From the pulp after expression, one may expect a yield of 45 per cent of juice or 12,000 kilograms per hectare. This juice contains 5 to 7 per cent of pure citric acid, which means 720 kilograms. This is evaporated to a specific gravity of 42° Beaumé, equal to an acidity

of 40 to 45 per cent. This liquid, neutralised with chalk, gives a citrate of lime, estimating 65 per cent of citric acid. To sum up, a hectare of lemon trees under favourable conditions of culture can produce: 100 kilograms of essence at 20 francs, worth 2,000 f.; 700 kilograms of citric acid at 3 f., worth 2,100 f.—in all, let us say, 4,000 f., admitting that the entire production is treated industrially, which is not usual. In any case, allowing an expense roughly estimated at 1,500 f. per hectare, the profit would be from 2,500 to 3,000 f. per hectare (= about £50 per acre).

LEMON AND LIME YIELDS AND PROFITS CONTRASTED

The material for Table XXXIX,[1] based on the foregoing figures, shows the relative yield in lemon and lime cultivations.

TABLE XXXIX

	Lemons (Pounds per Acre)	Limes (Pounds per Acre)
Yield of fruit	27,460	24,000
Yield of juice	10,560	11,550
Containing		
Citric acid	634	914
Oils	88	65{19 46

These figures indicate that the yield of fruit per acre in the case of lemons is greater than the yield of limes, taking four lemons to the pound; but the yield of juice and citric acid is considerably less. The amount of oils yielded, however, is greater in the case of the lemon.

It seems that the figure "275,000 lemons per hectare" given in the reference quoted above can be accepted as being representative of the average lemon grove. The English equivalent for the foregoing figure is 110,000 fruits per acre, and if there are 190 tons per acre, this gives a yield per tree of about 580 lemons, which corresponds with the average given by American authorities (Bulletin 190, Bureau of Plant Industry U. S. Dept. Agric.) and is well below the yields of the best lemon plantations.

When one comes to consider profits, it has to be remembered that the cost of handling the lemon crop is much greater than in the case of the lime crop. There are also expenses in connection with irrigation, frost protection, and manuring, and the rental value of good lemon land is higher than that suited to lime cultivation. On the other hand, lime cultivation has heavy shipping freights, though, as a matter of fact, these cannot on the whole work out much higher than those for lemons and lemon products, considering that Italy sends about half of its crop to the United States.

[1]Dunlap, 1915.

From the producer's point of view it is clear that the lime can easily compete with the lemon as a source of citric acid. In considering the figures given for lime cultivation, it should be borne in mind that these two are based on conservative estimates and the annual losses are allowed for, which in all probability will be greatly reduced in the near future, as improved methods of preparation are more widely adopted.

Prices are likely to drop in the future. For one thing, the war interfered with the consumption of fresh lemons and Sicily will probably make more citrate and oil. Lime cultivators will have to make every effort to improve their yields, which can be done, and to ship concentrated juice, only good quality raw juice, and essential oils. With greater production per acre lime-growers can stand a lower market value than the Sicilian growers. Moreover, the West Indies are nearer New York and Canada. Lime cultivation has the advantage over lemon-growing in Sicily in this respect also.

Selling basis of lime juice and oils.—Concentrated lime juice is sold on the basis of its citric acid content. The juice is quoted on the basis of a standard "pipe" of 108 gal., containing 64 oz. of acid per gallon. A pipe is therefore equivalent to 6,912 oz., or 432 lb. of citric acid.

A West Indian hogshead of concentrated juice (100 oz. per gallon) contains about 52 gal., and is equivalent to three-fourths of a standard pipe. A pipe contains 432 lb. of citric acid; a West Indian hogshead 325 lb. In commercial analyses the citric acid is mentioned as crystallized acid, containing only half a molecule of water instead of one molecule, as would be usual in the case of ordinary analysis.

Gross and net values.—Some idea of the net amount realized from the sale of concentrated lime juice can be obtained from the following figures. The expenses are partly fixed and partly based on value.

If the sale price per pipe is £21 the fixed charges (labor, freight, packing, etc.) amount to about £2 8*s.* 3*d.*, and the charges (commission, brokerage, insurance, testing), based on value, come to about 0*s.* 6*d.* (= 6½ per cent) on a hogshead (52 gal.), the amount realized for this hogshead gross is £15 16*s.*, hence the net value would be £12 7*s.* 3*d.* In the case of essential oils the charges based on value are higher (7½ per cent).

a) *Net value per acre.*—Owing to the variation in local conditions, it is not possible to give reliable figures as to the profits made in the case of lemon and lime cultivations, but, based on the values and charges noted above, the net value of lime juice and oil from an acre would be about £35. This does not allow for expenses of production previous to the preparation of the products and their shipment and sale.

According to the French estimate quoted on page 224, the clear profit in connection with lemon cultivation is about £45 per acre, but apparently this figure does not allow for the cost of marketing. The American authority quoted states that the profit in Italy on 100 lb. of oil and a pipe of citrate of lime is about $60 or £12 10*s*. Satisfactory information on the subject of profits can only be obtained from the accounts of an estate run on commercial lines.

THE MARKETING OF CITRUS PRODUCTS

Methods of selling in Sicily.—An important feature of the Sicilian industry which distinguishes it from the West Indian is the existence of the Camera Agrumaria or Citrus Chamber, the government agency for regulating market prices. The quotations which are made in London and in other markets by sellers are to a great extent based on the prices quoted by the Italian Citrus Chamber, so that from the West Indian point of view it is an organization of considerable interest. As a matter of fact, it may be laid down generally that the amount of organization employed in the disposal of Sicilian citrus products is very great—far greater than in the West Indies, where there exists no central body which can regulate the output in any way. In Sicily, the proprietors generally sell their crops by contract, before they are gathered, but have to fix a certain latest date for delivery. The sales are effected through intermediate brokers called "country brokers." Occasionally the crop is sold by the thousand at each picking. The buyer usually picks the fruit when it is sold by the season. The grower usually picks it when sold at each picking. Practically none of the fruit is exported by the grower, except occasionally in the case of experienced large producers. As already intimated, the grower usually sells his fruit through a broker to the exporter or the manufacturer of citrus products. The broker acts as an agent for both parties in the final settlement of the transaction, often shipping the fruit for the grower, receiving the money, and depositing it or using it in purchases for the grower.

The citrate of lime and concentrated lemon juice are handled exclusively by the Camera Agrumaria, that fixes the prices periodically and allots monthly deliveries to the various buyers all over the world through their (the buyers') agents. The lemon oil, however, is extracted by other firms, each having a distinctive brand for their oil and an agent in the principal markets for the sale of it. It will be seen from this that the Sicilian citrus trade lacks the competition among buyers which is enjoyed by the West Indian trade, and obtained by the methods referred to below.

West Indian methods.—In the case of the West Indies, each producer, in the ordinary way, ships his own produce; but he may sell the fruit to one of the larger factories. In one instance a government factory buys fruit or raw juice from the small growers, paying at once a certain percentage of cash and issuing a further amount in the form of a bonus at the end of the year, based upon the actual selling price of the manufactured products. Whatever the local method of disposal, the products are ultimately shipped to merchants at one or other of the principal markets. It should be mentioned here that a system of forward contracts is now being exclusively adopted in the West Indies. This should be distinguished from the Sicilian method of crop disposal already described. The West Indian forward contracts refer to the shipment of juices, citrate of lime, and oils within a definite period at a fixed price. This forward business could be vastly improved, to the mutual advantage of buyer and shipper, if the latter would contract to ship a certain specified quantity each month of the contract period and also to maintain a uniform standard.

Citrus products on the London market.—The methods employed in handling West Indian citrus products on the London market are very different from those employed in disposing of the Sicilian products, as will be seen from the following account.

As soon as a West Indian steamer arrives, the total available supplies of concentrated juice and citrate are communicated to the various buyers by the brokers, who invite best offers for the whole or part. The highest bid received by the brokers is then made to the various merchants who are interested, and they decide whether it is to be accepted or not. It is rarely refused, for it is generally recognized among the merchants that in this manner the highest price obtainable is secured, as there is always a demand for citric acid materials, and the buyer who needs it most naturally bids his utmost, knowing that he is in competition.

The raw juice and oils, however, are treated rather differently, for whereas the concentrated juice and citrate are always in demand, and are more or less necessities, the raw juice and oils are comparative luxuries, and generally offered in more than sufficient quantities to meet the demand, which is spasmodic. Therefore, the sale of these products is slower, and requires sometimes a great deal of negotiation.

The samples of the different shipments are exhibited at the broker's salesroom, and the prospective customers are notified of fresh arrivals. Samples are also mailed to buyers resident in the country or abroad.

It will be noticed here that the system of sales adopted in the case of citrus produce differs from that employed in the case of staples like

cacao or sugar or rubber. In these there is an open sale—an auction; in the case of citrus, the produce is sold by private agreement. It may be questioned whether this system of conducting private sales is in the best interests of the growers. There seems to be a feeling that it is quite as satisfactory, for buyers will often give higher prices privately than they will in public; and, moreover, the broker is better able to find the best buyers, being in touch with their individual requirements.

Defects in West Indian products.—It would seem that the importers of West Indian citrus products have, as regards production, several comments to make that seem quite justified. The quality of citrate of lime from the West Indies is regarded as highly satisfactory, but as regards raw lime juice, there is said to be a tendency to ship inferior grades, and heavy arrivals of lower qualities sometimes depress the market. The casks are not always clean, and often the percentage of pulp in the juice is undesirably high. It is strongly urged in London that to maintain a steady trade in raw lime juice at remunerative rates inferior qualities should not be sent.

The shippers would ultimately reap the benefit by the better price obtained for their smaller output, for there really exists a demand for a good juice of uniform quality. It should be of bright greenish tint, with a small percentage of pulp (floating preferred). It should not be contaminated with iron, and should contain the average percentage of acid. Juice of low test or bad color is absolutely neglected by buyers while anything else is available, and it does not improve on keeping. Raw juice imported from Jamaica very frequently sells at good prices. This is believed to be the result of the presence in it of oil which preserves the juice.

In endeavoring to obtain information concerning the marketing of concentrated juice, Dunlap was enabled, through the courtesy of Messrs. Ogston & Moore, to compare samples of lemon and lime juice. Generally speaking, it appears that the Sicilian concentrated juice arrives in a much brighter condition than the West Indian product. Another important point is that Sicilian lemon juice (concentrated) is always of about the same test, whereas the West Indian varies from 50 oz. to 140 oz. of citric acid per gallon, making it very difficult for buyers to know what they are getting. It is also worth noting that the calico dyers in Manchester state that West Indian concentrated juice often contains more sediment than is desirable. Because concentrated lemon juice arrives in a more fluid state than lime juice, its employment in the textile trade is facilitated; and, what is equally important to the grower, this condition of the lemon juice makes sampling easier. Messrs. Ogston & Moore state that the variation in the acid content of samples from the same cask of concentrated lime juice is largely due to the viscous nature of the fluid. In connection with sampling and testing there are many dif-

ficulties, as is well known to both buyers and growers. It must be borne in mind, however, that the fluctuations work both ways: sometimes an analytical result may favor the grower, at other times the buyer. It is well to mention here that samples of imported citrus products are generally taken at the wharves as soon as the ship is unloaded. In some instances samples go direct, but this is the exception, as the broker is supposed to examine a sample from each shipment and report upon it where necessary. Brokers make themselves familiar with samples in order that they may recommend certain marks for special purposes. The samples are analyzed in duplicate, and are kept for future reference.

Lime and lemon oils.—In concluding this section, a few words may be said concerning the market characters of citrus oils. Citrus oils should be packed only in the best tins, and on no account should distilled oil be mixed with hand-pressed (écuelled). It should be remembered, in considering Sicilian competition, that the West Indian lime oils are used in the toilet and confectionery trades for different purposes from the lemon

TABLE XL

Year	Gal.	£	Year	Gal.	£	Year	Gal.	£
1892.....	1,127	87	1900....	4,446	4,104	1908....	4,860	4,659
1893.....	1,346	1,877	1901....	3,907	2,866	1909....	5,403	5,239
1894.....	1,469	1,051	1902....	5,709	3,207	1910....	6,780	5,875
1895.....	1,561	1,762	1903....	3,050	1,493	1911....	6,364	5,401
1896.....	1,942	3,364	1904....	2,804	860	1912....	5,207	4,834
1897.....	2,884	4,713	1905....	4,163	1,947	1913....	6,875	9,833
1898.....	3,560	4,432	1906....	4,706	3,016	1914....	5,603	10,138
1899.....	3,587	4,492	1907....	4,675	4,133			

The great hurricane which struck Montserrat in 1899 contributed very considerably to the progress in Dominica. Many Montserrat laborers and their families sought refuge in Dominica and as they knew the work of the lime industry they helped to develop the increased output. The retrogression of the years 1903 and 1904 was caused by great drouth and insect pests.

Besides the fine, hand-pressed lime oil the foregoing figures also include the inferior distilled oil which is used in the United States in fairly considerable quantities.

oils. Hence, whatever the Sicilian production—which cannot increase largely if the fresh fruit trade holds—there will always be a special demand for lime oils from the West Indies, provided that they are of good and uniform quality. In this business, too, the Sicilians have been longer in the field and their lemon oils are prepared with the greatest care, resulting in a uniform article, so that buyers know they can rely upon always getting the same quality. Hand-pressed lime oil, on the other hand, varies tremendously, even from the same estate, and it

[1]*Report of Schimmel & Co.* (April–October, 1916), p. 36. The exports of lime oil from Dominica (Gildemeister and Hoffman) during the years 1892 to 1914 are illustrated by Table XL.

would be a wise step for a planter to bulk, say, two or three months' product of hand-pressed oil (keeping out any of bad color) and shipping only two or three times during the season. This would give him a more regular quality and his mark would[1] gradually become known.

Oils of orange.—These oils, both bitter and sweet, have been produced in large quantities in Italy for many years. Like the oils of lemon and lime, those of the orange are used in perfumery and confectionery. Before the Messina earthquake, which destroyed large quantities of oil in Sicily, the West Indian product had been too inferior to compete with the Sicilian, but necessity led to the partial substitution of West Indian orange oil for Sicilian. It is worth noting that as the demand sprang up the oils in Jamaica improved, and it is believed that good prospects lie before West Indian orange oils, provided that only good qualities are shipped. The cost of collection, preparation, and freight appears to be greater in Jamaica than in Sicily, and it would scarcely seem to pay at less than 4*s.* per pound.

SUMMARY

1. The output of lime products in the tropics, although comparatively small, is rapidly increasing. The Sicilian production of lemons is, on the other hand, stationary, but, according to the demand of the world's market, the United States can increase her output of citrate at the expense of fresh lemons, and vice versa. Lime growers can do the same to a certain extent, but are less able to exert influence in this respect.

2. An examination of figures relating to the composition of the lemon and lime shows that the lime is richer in juice and citric acid than the lemon, but the lemon generally contains more essential oil.

3. As regards cultivation the two crops differ in many respects. Lemon cultivation seems the more expensive owing to the necessity for irrigation, frost protection, and handling, but lemon products can be placed on the European market at less expense than lime products.

4. For purposes of comparison, the lemon may be regarded as yielding 634 lb. of citric acid per acre against 914 lb. in the case of limes. The figures for essential oils are 88 lb. and 65 lb. respectively.

5. In view of the probable increase in the Sicilian output of citrate, lime-growers might with advantage increase their shipments of concentrated juice of uniform density (about 100 oz. of citric acid per gallon). Only raw lime juice of the best quality should be shipped. Since lime oils are used for different purposes from lemon oils, they cannot be said to come into direct competition unless the qualities of one (lemon oil)

are so inferior as to permit of the substitution of the other. Oils take longer to sell than other citrus products. Lime oils are on the whole more variable than lemon oils.

6. It is not possible on the basis of available information to compare the profits from lemon and lime cultivation. With good prices it is probable that it is greater in the case of limes.

7. As regards marketing, the existence of the Sicilian Camera means lack of that competition among buyers which is enjoyed by the lime-growing industry. At the same time the Camera insures a minimum price for lemon-growers.

8. There is a very great variation in the composition of citrus juices offered in the market.

9. A profitable trade in orange oils might be more generally established in the West Indies.

EUROPEAN CITRIC ACID PRODUCTION

CALCIUM CITRATE

The output of calcium citrate in Sicily in 1913 was 6,000 tons, besides 800 pipes of concentrated juice; in 1914 the output was 6,687 tons, and in 1918, 9,087 tons. The mean price fixed was £52 per ton in 1905, £80 in 1907, £50 in 1909, and £53 12*s.* in 1910. In 1909, owing to the economic crisis, exportations diminished considerably and in certain months the price fell to £40 per ton. During the war the sale price for the citrate (64 per cent) was fixed at 280 pounds per ton for the years 1917–19.

The Sicilian exports and imports of calcium citrate (in casks called pipes, holding 305 kilos) were as is shown in Table XLI (especially to the United States, France, and Great Britain).

TABLE XLI

	1905	1908	1910	1912	1913	1914	1915	1916	1917	1918
Tons.....	4126	7710	6476	7680	3813	5688	6704	7279	5838	3736
Value £ 1000	181	401	414	488	242	428	509	553	724	463

In 1913, the freight for calcium citrate from Sicily to Marseilles was about 10*s.* per ton, and to London, 16*s.*

In the West Indies the crude citrus materials produced corresponded with 1,000 tons of calcium citrate in 1913 and with 1,200 tons in 1914.

CITRIC ACID

The annual production of refined citric acid in Europe was about 4,000 tons in 1913, and the price varied from £108 to £140 per ton. In

general the price rises and falls with that of tartaric acid, the difference between the prices of the two acids being due to the different degrees of acidity (three carboxyls in citric acid and two in tartaric acid) and molecular weights (148.9 for tartaric acid ($+H_2O$) and 208.5 for citric).

If all the juice transformed in Sicily into calcium citrate for exportation were made into citric acid, the annual output would amount to 3,000 to 4,000 tons, which would suffice to supply the whole of Europe.

The import duty in Italy was formerly £4 per ton, but was raised in 1909 to £20 to protect a large factory, with £40,000 capital, erected in 1910–11 near Palermo; during the war this factory became solely Italian, with the title Fabbrica Chimica Arenella, and it now supplies Italian needs for citric acid and is able to export a considerable quantity which formerly was not made in Italy, the manufacture there stopping with the production of citrate of lime.

The citric acid imported into and exported from Italy (Calabria and Sicily) is shown in Table XLII.

TABLE XLII

	1908	1910	1912	1913	1914	1915	1916	1917	1918
Imports (tons).	164	109	127	105	32	18	26	.....	.....
Value (pounds).	24,332	.....	18,870	.....	7,040	5,370	7,890	.....	.....
Exports (tons).	2.3	0.8	2.3	220	599	755	1,045	832	754
Value (pounds).	.....	.....	.....	32,634	131,736	226,650	313,380	349,440	316,596

The output of citric acid in Italy in 1912 was still below 200 tons, and in 1914 it reached 800 tons, the capacity of the factories being 1,600 tons.

The French imports and exports in tons are shown in Table XLIII.

TABLE XLIII

Citric Acid		1913	1914	1915	1916
Juice	Imported	134	58	19	146
	Exported	31	12	11	131
Crystals	Imported	29	58	37	95
	Exported	452	249	272	207

For Germany the imports and exports in tons are given in Table XLIV.

TABLE XLIV

	1902	1905	1909	1910	1911	1912	1913
Imports....	306	.....	193	206	178	162	310
Exports....	163	379	358	381	553	550	528

In addition, 360 tons of lemon juice were imported into Germany in 1908 and 170 tons in 1909.

In Austria there were in 1906 two citric acid factories, which imported 54 tons of calcium citrate from Sicily, 145 tons from Turkey, and 435 from Greece. France had then two factories, these importing 1,811 tons of Sicilian calcium citrate in one year. In Germany there were nine citric acid works and four of pure citrates, 1,318 tons of Sicilian calcium citrate being imported in 1908. In England there were ten works, almost all in London. The United States has very large factories which produce more than 1,000 tons of citric acid and import also a certain quantity from Europe, although the protective duty was over $150 per ton; calcium citrate, which was all imported (in 1911 about 2,800 tons, of the value $180,000), is free from duty.

COST OF MANUFACTURE OF ORANGE VINEGAR

With prices changing as they have been, it is impossible to estimate accurately the costs of equipment, material, and production. However, the price of apparatus was obtained in January, 1920, and approximate costs of production at that time can be estimated from figures as received from apple vinegar manufacturers. Summaries only will be given here, but the costs of manufacturing in detail will be found in an article by E. M. Chace and H. D. Poore.

EQUIPMENT

The equipment for a small plant using a hand-power hydraulic press, with a capacity of 250 gal. per day, would cost about $2,000. A 2,500-gal. or 50-barrel plant would reach $3,500 using a steam-power hydraulic press. A continuous type press would add about 50 per cent to this estimate. For a 100-barrel plant, the figures given can be doubled. The prices include pasteurizing, bottling, and filtering machines which cost $800 would be unnecessary if the product is barreled.

MATERIAL

Frozen fruit can be obtained for the cost of hauling, about $3 per ton, while sound fruit will run from this amount to $20 per ton. Frosted oranges will yield as low as 40 gal. per ton, while sound fruit will average about 70 gal.

PRODUCTION COSTS

Apples yield as high as 180 gal. of juice per ton, so that the figures obtained from vinegar manufacturers, which also included the cost of apples, are not comparable for oranges. However, all things considered, 10 cents a gallon should cover the cost of production, including overhead.

Table XLVI shows the cost of production per gallon under various conditions, based on a yield of 70 gal. per ton. Where frozen oranges are used, with a 40- to 50-gal. yield, the cost per gallon of raw juice would be about seven cents.

COMPARISON WITH APPLE VINEGAR

Apple vinegar in bulk retails as low as 35 cents per gallon, so that with oranges at over $5 per ton, there is little chance to compete with cider vinegar. But put up in quart bottles under well-established brands, the product may compete with the fancy grades of cider vinegars, which retail in quart bottles from 80 cents to $1.40 per gallon.

TABLE XLV

CHANGES IN COMPOSITION OCCURRING DURING THE GENERATOR PROCESS (FROM POORE)

Lot Number	4				5			
	Fresh Juice	Fermented Juice	A*	Vinegar	Fresh Juice	Fermented Juice	A*	Vinegar
Total acid as citric	1.14	1.13	.....	.....	1.14	1.14	.....	.....
Total acid as acetic	.....	.....	2.53	4.74	.....	.....	2.63	4.70
Fixed acid as citric	1.12	1.03	1.09	1.07	1.13	1.07	1.07	1.04
Volatile acid as acetic	.....	0.09	1.50	3.74	.....	0.07	1.63	3.73
Total solids	13.39	3.64	4.26	4.34	13.49	3.43	3.81	4.02
Total sugars as invert	9.91	.....	.....	0.20	9.87	.....	.....	0.17
Alcohol per cent by (volume)	.....	5.73	3.55	0.43	.....	5.75	3.48	0.37
Total ash	.....	0.48	0.60	0.61	.....	0.46	0.52	0.55
Water-insoluble ash	.....	0.10	0.17	0.17	.....	0.09	0.12	0.14
Water-soluble ash	.....	0.38	0.43	0.44	.....	0.37	0.40	0.41
Alkalinity of water-soluble ash (cc.0.1 N/HCl per 100 cc.)	.....	51.2	56.1	55.2	.....	50.0	52.1	53.2

*The calculated analyses of the mixture consisting of the vinegar left in the generator from the previous run and the fermented juice of this run.

CITRUS OIL PRICES[1]

As Meldrum[2] has pointed out, the history of the price fluctuations for essential oils has shown a rhythmic rise in prices with strengthening demand followed by overproduction and consequent price depression. It should be noted, however, that the influences of speculation often have a marked effect on the essential oil market. It is not uncommon for prices to be suddenly forced up and artificially maintained apparently without any sound commercial or economic reason. Prices for the individual oils, shown in the tables on pages 367–74, are discussed on page 238.

[1]See Appendix, pp. 349–51, 363, 367–74, for detailed statistics on quantities and values for 1898–1924.

[2]W. B. Meldrum, "Prices of Essential Oils, Flavoring and Perfume Materials," *War Industries Board Price Bulletin*, No. 50, Washington (1919).

TABLE XLVI

PRODUCTION COST PER GALLON OF ORANGE VINEGAR

Cost per Ton of Fruit	Cost per Gallon Raw Juice	Total Manufacturing Cost and Overhead	Bottles and Caps (C. L.)	Labels	Breakage, Waste, etc.	Cooperage	Loss	Total
Best Labels and One-Fifth Gallon Bottles								
$ 3.00	$0.043	$0.10	$0.264	$0.01	$0.009	.....	.....	$0.426
5.00	0.071	0.10	0.264	0.01	0.01	.....	.....	0.457
10.00	0.143	0.10	0.264	0.01	0.011	.....	.....	0.528
15.00	0.214	0.10	0.264	0.01	0.013	.....	.....	0.601
20.00	0.286	0.10	0.264	0.01	0.014	.....	.....	0.674
Cheaper Labels and Full Quart Bottles								
3.00	0.043	0.10	0.271	0.006	0.009	.....	.....	0.429
5.00	0.071	0.10	0.271	0.006	0.010	.....	.....	0.458
10.00	0.143	0.10	0.271	0.006	0.011	.....	.....	0.531
15.00	0.214	0.10	0.271	0.006	0.013	.....	.....	0.604
20.00	0.286	0.10	0.271	0.006	0.014	.....	.....	0.677
In Old Whisky or Brandy Barrels								
3.00	0.043	0.10	.....	.....	.....	$0.11	$0.003	0.256
5.00	0.071	0.10	.....	.....	.....	0.11	0.003	0.284
10.00	0.143	0.10	.....	.....	.....	0.11	0.004	0.357
15.00	0.214	0.10	.....	.....	.....	0.11	0.005	0.429
20.00	0.286	0.10	.....	.....	.....	0.11	0.005	0.501
In Old Vinegar Barrels								
3.00	0.043	0.10	.....	.....	.....	0.06	0.003	0.206
5.00	0.071	0.10	.....	.....	.....	0.06	0.003	0.234
10.00	0.143	0.10	.....	.....	.....	0.06	0.004	0.307
15.00	0.214	0.10	.....	.....	.....	0.06	0.004	0.378
20.00	0.286	0.10	.....	.....	.....	0.06	0.005	0.451

TABLE XLVII

ANALYSES OF VINEGARS MADE BY THE GENERATOR PROCESS

(Results in Grams per 100 c.c.)

	2		3	4		5		A*
Elapsed time in months between date of preparation and date of analysis	2	9	0	0	4	0	4	
Specific gravity 15.6/15.6	1.0209	1.0224	1.0277	1.0229	1.0240	1.0217	1.0225	.....
Alcohol per cent by (volume)	0.36	0.07	0.03	0.43	0.34	0.37	0.26	.....
Glycerol	0.25	0.22	0.24	0.22	0.23	0.21	0.21	.....
Solids	3.82	4.03	5.26	4.34	4.50	4.02	4.12	2.49
Non-sugar solids	.....	3.81	.....	.....	4.21	.....	3.88	.....
Total reducing substances before inversion	0.16	0.25	0.19	0.20	0.33	0.17	0.25	0.25
Reducing sugars before inversion after evaporation	.....	0.22	.....	.....	0.29	.....	0.24	.....
Reducing sugars after inversion	.....	0.22	.....	.....	0.29	.....	0.24	0.25
Total ash	0.52	0.54	0.79	0.61	0.64	0.55	0.57	0.34
Water-insoluble ash	0.15	0.16	0.29	0.17	0.17	0.14	0.15	.....
Water-soluble ash	0.37	0.38	0.50	0.44	0.47	0.41	0.42	.....
Alkalinity of water-soluble ash (c.c. 0.1 N/HCl per 100 c.c.)	44.0	48.0	64.0	55.2	57.2	53.2	54.0	.....
Total P_2O_5 (mg. per 100 c.c.)	44.9	45.6	53.0	38.8	41.9	35.1	36.3	34.8
Total acid as acetic	4.72	5.02	4.91	4.74	4.98	4.70	4.91	.....
Fixed acid as citric	1.00	1.00	1.20	1.07	1.07	1.04	1.04	0.11 (malic)
Volatile acid as acetic	3.79	4.08	3.79	3.74	3.98	3.73	3.93	4.84
Protein (N X 6.25)	.....	0.75	.....	.....	0.61	.....	0.56	.....
Lead precipitate	V. H.	V. H.	V. H.	V. H.	V. H.	V. H.	V. H.	.....
Alcohol precipitate	.....	1.06	.....	.....	1.12	.....	0.95	.....

*These results, which are inserted for comparison, are taken from page 761 of *Food Inspection and Analysis* by Leach, and give the average analyses of twenty-two samples of cider vinegar of known purity made by H. C. Lythgoe.

Lemon oil.—During 1913 the price of lemon oil was unusually high and in August, 1913, it reached $4.75 per pound. The latter months of 1913 saw the beginning of a gradual decline and during the first quarter of 1914 the price had dropped as low as $2.45. Prices continued to fall and the average for the entire year of 1915 was $1.075 per pound.

The lowest price in recent years was reached during August and September of 1916, when the oil was quoted at 90 cents per pound. There were occasional fluctuations during 1917, 1918, and 1919, but this is not shown by the yearly averages, which were as follows: 1917, $1.125; 1918, $1.158; and 1919, $1.275.

Orange oil.—During the period 1913 to 1915 orange-oil prices followed the same general decline as did those for lemon oil. The yearly averages were as follows: 1913, $3.3135; 1914, $2.475; and 1915, $1.70. In May, 1916, the price had increased to $2.85, and in October to $3. This high level was maintained during 1917 and for most of 1918. Toward the end of 1919 a further increase brought the price up to $3.25 per pound.

Oil of bergamot.—The average prices for bergamot oil during the last seven years have been as follows: 1913, $6.0667 per pound; 1914, $5.45 per pound; 1915, $3.2125 per pound; 1916, $4.20 per pound; 1917, $5.9792 per pound; 1918, $6.0708 per pound; 1919, $5.7375 per pound.

From $6.50 per pound in January, 1913, the price dropped to $3 in April, 1915, but since that time there has been a gradual increase which reached a maximum of $7.50 in October and November, 1918. Synthetic oil of bergamot, although of somewhat lower price, has followed the same general trend as the natural product.

Oil of limes.—Price quotations for oil of limes are shown only occasionally in the *Oil, Paint, and Drug Reporter.* The price of the expressed oil varied between $3 and $4 per pound during 1914, 1915, 1916, and 1917. In January, 1918, expressed oil of limes was quoted at $5.75 to $6, and in January, 1919, at $4.90 to $5. Distilled oil of limes was quoted at 75 cents in August, 1914, but by the beginning of 1916 the price had advanced to $2.50, and this level, with only a little variation, has been maintained since that time.

Oil of Neroli.—Several varieties of this very valuable essential oil are shown in the price quotations. For a year and a half prior to the war, oil of Neroli petale, was quoted at $45 per pound. In July, 1914, fear of a short crop caused a rise to $51 and further increase to $60 followed in October. During 1915, however, there was a return to the pre-war level, which was maintained during 1916, and the first half of 1917. Short crops and labor difficulties at that time caused an increase to $85 in

October, 1917, and to $90 during November and December of 1918. Supplies continued to be short during 1919, and by the end of the year oil of neroli petale had reached $130 per pound. Oil of Neroli Bigarade generally commands a slightly lower price and in January, 1920, it was quoted at $120. A synthetic neroli has been quoted since 1918 and has varied in price from $15 to $30 per pound.

Citrus oils imported into the United States for the most part do not compete with domestic products. Lemon and orange oils are produced in this country, but as yet the industries are able to supply only a relatively small proportion of the consumption. Since lemon and orange oils are by-products of the citrus industry, it may be urged that their complete recovery will utilize inferior grades of fruit which at present are wasted. In this way their recovery would strengthen the citrus industry without increasing the prices for its principal products. On the other hand, these articles require a large amount of hand labor and for that reason they cannot be prepared under the same methods as cheaply in the United States as abroad. The application of machine methods has been tried and has undoubtedly lowered the cost of production, but the products thus obtained are not identical with the hand-pressed oils and are of less value. Superior methods of cultivation used in America have resulted in a smaller proportion of "culls" or inferior fruit than is obtained abroad—and it is therefore doubtful whether a domestic citrus products industry can ever be developed sufficiently to supply the entire American demand.

The imposition of a duty on the citrus oils by the United States in 1913 has had little if any effect upon the volume of the imports, and has resulted in an annual revenue of about $135,000. These oils are used in the manufacture of perfumes, and flavors for soft drinks, and confections, and in this connection may be regarded in the class of luxuries. However, in establishing the rates of duty on these oils, consideration should logically be given to the rates imposed upon the finished products —perfumes and flavors.

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CHAPTER XII

THE INDUSTRY IN NORTH AMERICA

CITRUS OIL PRODUCTION

Orange and lemon oils are the only citrus oils prepared on a commercial scale in the United States. In comparison with the large production in Italy, the domestic output is insignificant. The production of lemon oil, which is limited to California, was estimated in 1917 at 6,000 lb., or about 1 per cent of our imports. The domestic production of orange oil during the same year was declared to be negligible.[1]

IMPORTS OF CITRUS OILS

Imports of all essential and distilled oils had increased in value from $2,118,102 in 1910 to $4,905,157 in 1913. The imports declined until 1916, from which time they showed a gradual increase, amounting in 1918 to $3,948,059. Of the total imports of essential oils, about 30 per cent are represented by citrus oils, as may be seen in the table on page .

Lemon oil.—Imports of lemon oil prior to the war showed little variation in quantity, averaging about 400,000 lb. The considerable variation in value, however, is shown by the fact that in 1910 imports of 415,819 lb. were valued at $310,543, while in 1913, 400,424 lb. were valued at $794,215—an increase of over 100 per cent. Since 1914 there has been a slight increase over pre-war imports, notwithstanding the fact that since October, 1913, lemon oil (formerly on the free list) has been dutiable at 10 per cent ad valorem. Imports for the period 1915–19 averaged 494,613 lb., valued at $434,734.

The decrease in imports during the fiscal year 1919 was probably caused by the fact that the Italian government during 1918 requisitioned a large part of the oil of lemon output to be used as a substitute for turpentine, sorely needed in that country for use in painting battleships and other military equipment. Over 95 per cent of the imports of lemon oil are furnished by Italy.

Orange oil.—Imports of orange oil have been much less than those of lemon oil, but have shown considerably wider variation. Imports in 1912 amounted to 97,065 lb. valued at $168,831 and in 1913 to 79,797 lb. valued at $155,299. There has been a considerable increase since

[1]See *War Industries Price Bulletin,* No. 50.

1914; imports in 1918 were more than double the average pre-war imports.

Oil of bergamot.—Maximum imports in recent years were received in 1908 and amounted to 94,967 lb. valued at $284,173. For three years prior to the act of 1913, imports had averaged about 65,000 lb., but in 1914, simultaneously with the imposition of a duty of 20 per cent, imports decreased to 36,500 lb. Since that time the imports have shown a tendency to increase and in 1916 surpassed the 1913 figure. The value per unit quantity has varied from $4.84 in 1913 to $2.56 in 1916. Hand-pressed bergamot oil has come almost entirely from Italy, but before the war Germany furnished the United States with considerable quantities of artificial bergamot oil and also with certain highly refined grades.

Oil of limes.—Imports of oil of limes have shown variation both in quantity and value. In 1908 the imports amounted to 6,765 lb. valued at about 75 cents a pound, and in 1918 they reached 29,137 lb. valued at over $2.50 per pound. The imposition of a duty on oil of limes in 1913 had no noticeable effect upon the imports.

Neroli or orange flower oil.—Maximum pre-war imports of neroli were received in 1913 and amounted to 38,365 lb. valued at $171,932. During 1914 and 1915 there was a decrease of about 30 per cent in the imports but in 1916 and again in 1918, imports were in excess of 30,000 lb. The value per unit of quantity has varied from $10.50 per pound in 1908 to $1.93 in 1916.

Cedrat oil.—Only a very small quantity of cedrat oil is imported into the United States. The maximum imports in 1915 were 788 lb. valued at $3,721. The large variation in value is probably due to the fact that various fictitious oils are offered under the name of *cedrat,* and that the genuine oil from *Citrus medica* is rarely met with in commerce.

THE CITRATE AND CITRIC ACID INDUSTRY

The citrate of lime and citric acid industry in the United States is divided into two distinct branches. Three firms, located along the Atlantic Coast, specialize in the manufacture of citric acid and citrates from citrate of lime, imported chiefly from Sicily, or made from concentrated juices of citrus fruits, imported chiefly from the Dominican Republic.

In California there are several firms which make citrate of lime and citric acid from lemons. Some of these western firms ship citrate of lime to the eastern manufacturers. One firm has been operating for about 27 years; the others have all begun operation since 1915.

The manufacture of citric acid in the United States is shown in Table XLVIII. The figures for 1904, 1909, and 1914 are taken from the United

States census. The figures for 1915, 1916, and 1917 are compiled from reports made to the United States Tariff Commission by the manufacturers.

TABLE XLVIII

CITRIC ACID MANUFACTURED IN THE UNITED STATES 1904–17

Year	Quantity (Pounds)	Year	Quantity (Pounds)
1904	2,265,631	1915	3,417,795
1909	2,102,256	1916	4,188,538
1914	2,729,943	1917	4,032,297

IMPORTS OF CITRATE OF LIME AND CITRIC ACID

The table of imports (pages 352–53) show that the amount of citric acid imported as such is small in comparison with the imports in the form of citrate of lime. Since the imports of citric acid during the years 1910–12 exceeded the exports from Italy, it is obvious that this acid must have come from European countries other than Sicily. Under the Tariff Act of 1909, with citrate of lime on the free list and citric acid dutiable at 7 cents per pound the imports of citric acid dwindled to an insignificant amount. The Tariff Act of 1913 put a duty of 1 cent per pound on citrate of lime, and lowered the duty on citric acid from 7 cents per pound to 5 cents per pound. These changes in duties, which occurred almost simultaneously with the development of the manufacture of citric acid in Italy (see Table XLII), were followed by a large increase in imports of citric acid from 8,677 lb. in 1913 to 652,210 lb. during the 1914 fiscal year and to 722,434 lb. during the 1915 fiscal year.

TARIFF PROBLEMS

Citrate of lime and citric acid present two distinct tariff problems. The first problem is the general one, whether these articles should be placed on the free list, or subject to a duty for the purpose of raising revenue or for the protection of an American industry. The tariff treatment is necessarily related to that of lemons, the major product of the industry, which are now given a protective duty. There is, however, a difference between the two products—lemons and citric acid—in that lemons are an agricultural product with no mechanical or technical processes, whereas the manufacture of citric acid presents new technical and commercial problems. It may be urged, further, that the full recovery of the by-products will utilize a material formerly wasted and will strengthen the lemon industry without raising the price of lemons to the public. On the other hand, it is not likely that the by-product industry will develop sufficiently to supply the entire American demand

unless the duty is made so high as to result in the use of fruit of good enough quality to be salable as fresh fruit and to exclude the by-products from abroad made from cull lemons.

The second problem is the proper relationship between the rates of duty on citrate and citric acid made therefrom. Prior to the passage of the 1913 Tariff Act citrate of lime was free and the margin in favor of the acid was 7 cents per pound, which shut out the foreign acid almost entirely. The imposition of a duty of 1 cent per pound on citrate of lime did not decrease imports, and it raised over $60,000 revenue per year. At the same time that this duty became effective there was a reduction in the duty on citric acid from 7 cents to 5 cents per pound, and at about the same time there was a development of the manufacture of citric acid in Italy. The result of these changes in competitive conditions was an increase in imports of citric acid to about 15 or 20 per cent of the consumption during 1914 and 1915, an increase sufficient to furnish some competition to the domestic industry. During recent years there has been a fall in imports, resulting in part at least from war conditions.

CALIFORNIA

The citrus by-product industry in southern California is located in those counties that raise most of the citrus fruit, viz., Santa Barbara, Ventura, Los Angeles, Orange, Riverside, San Bernardino, and San Diego. The chief cities interested follow the periphery of a triangle whose vertices lie at Los Angeles, San Bernardino, and San Diego.

Cultural conditions are generally the same for the entire area. The cost of fruit production therefore as well as the percentage of culls is nearly equal over the entire citrus belt. Transportation charges, however, constitute a factor of importance in the location of successful by-product plants.

It is manifestly less costly to sort and pack the fruit than to transform it into oil and citrate, but, on the other hand, it is less difficult to transport these final products than the original fruit, which requires such careful handling and is subject to decay.

By-products offer a more tempting field for speculation, citric acid keeping indefinitely, while large quantities of oil may be held over from crop to crop to secure a satisfactory price.

During 1924 over 2,000 carloads of lemons were processed, producing 30,000 pounds of pectin, 60,000 pounds of lemon oil, and 1,000,000 pounds of crystallized citric acid.

At the present time there are fourteen concerns listed as producing five main products. There are four concerns producing citric acid, one

producing citrate of lime, seven producing peel in one form or another, five producing juice, and three producing oil. Some of the firms listed are recent and may possibly not endure as permanent commercial concerns. The by-product industry has undoubtedly, however, taken great strides in the past few years. Two of the citric acid plants are of very large capacity. Both could undoubtedly exceed 10,000 tons capacity per annum, if necessary. Indeed, with no very serious alterations, it would be possible to increase the capacity to twenty thousand tons each. The third citric acid plant has a capacity of 2,500 tons and the citrate of lime plant a capacity of 8,000 tons or more. A very conservative estimate of the entire capacity for handling lemons of the four plants as they stand today would be from 30,000 to 40,000 tons.

Practically all of the oranges absorbed for by-products at the present time are going into marmalade factories. One concern alone has a capacity of about 5,000 tons of fruit, and estimates of the other concerns now operating vary from 5,000 to 10,000 tons.

This state of affairs has also been reflected in the price of cull fruit during the past few years. Up until 1915–16, it was not at all difficult to secure cull oranges and lemons at $5 per ton for sound culls. During the season of 1919 when the crop conditions were nearly normal, it was necessary to pay from $20 to $30 a ton for material of the same grade. Whether these prices will continue, with competition from foreign products, and in seasons when the crops are abundant, is a matter of some doubt. There are a number of citric acid and citrate manufacturers who are in the market to purchase cull lemons at prices which could hardly be realized by the small producer from the sale of citrate alone.

Apparatus for the manufacture of oil from both oranges and lemons is now under construction in more than one place in the state, but has not been sufficiently developed to be available to the average fruit-grower.

The market for lemon peel in brine, candied or dried peel, seems limited at present, and none is produced unless contracted for in advance.

The question of the disposal of the unsalable oranges has scarcely been solved by their use in marmalade, enormous quantities of which having been manufactured. Professor Cruess, of the University of California, suggested, in the *California Cultivator* of January 11, 1919, a method of canning orange marmalade stock, i.e., the fruit without sugar. It is true that the amount of marmalade made in 1919 was probably not excessive when compared with some other preserves already on the market, but it must be remembered that orange marmalade must make its way by displacing to some extent other material more or less firmly

established in the menus of American homes. The increase in production of this commodity in California in that year was estimated at approximately 500 per cent and would have been more than double that if all the frozen fruit had been taken care of in this way.

The question of manufacturing orange vinegar on a large scale to compete with eastern cider vinegar is a matter for consideration in the future. At the present demand for culls, however, together with increased freight rates and cost of cooperage, there seems to be no chance of competing in middle western or eastern markets with cider vinegar. The vinegar can be made of excellent quality, of fine fruity flavor, but it has not a characteristic orange flavor.

There has been some demand for dried orange peel, for use in mince meat, and also, it has been rumored, for use in chewing tobacco. Several carloads went East in 1917 and the demand will probably continue until a foreign product appears on the market, when it will be a question of cheaper production or tariff protection. Candied peel is readily made but the consumption is not large. No method has been developed for producing a first-class merchantable orange juice.

Grapefruit can be used in the preparation of marmalades, a very desirable product being made to contain as high as 33 per cent.

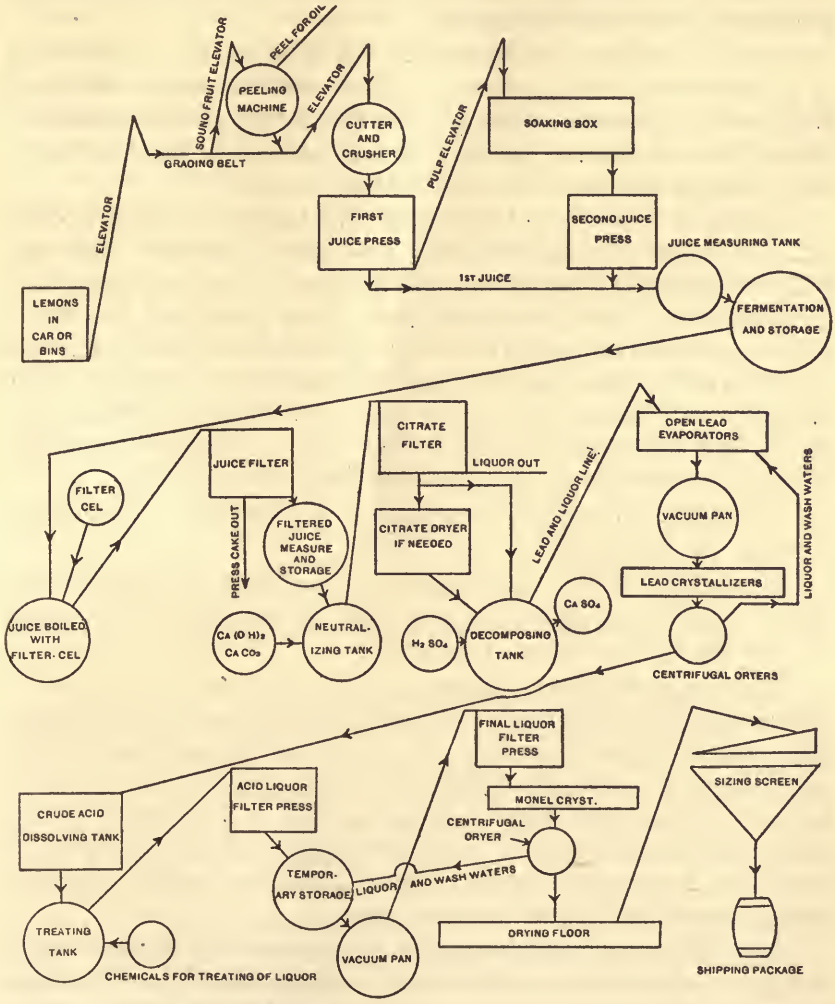
Satisfactory candied peel of grapefruit is also easily produced on a large or small scale (see chap. iv). The equipment is inexpensive and easily obtained. Where large quantities are put up, the time can be shortened very materially by the use of the vacuum pressure methods. Here an autoclave is used for heating the peel under high vacuum, followed by a heating in syrup under pressure. The impregnation is hastened in this way and a clear article is produced. This candied peel can be cut into very thin strips and used in marmalade very satisfactorily.

It is possible to prepare a satisfactory beverage from grapefruit, although the use of frozen material in its preparation is questioned. The great trouble with California grapefruit juice is the same difficulty that gives California grapefruit itself its generally poor reputation, i.e., immaturity. Few California grapefruit growers are willing to allow their fruit to mature before harvesting it, a fact to which A. D. Shamel, of the United States Department of Agriculture has repeatedly called attention.

THE MANUFACTURE OF CITRIC ACID FROM LEMONS

The first serious attempt to convert the lower grades of California lemons into by-products was made in 1898 at National City, San Diego County.

Other factories for the production of various products from citrus fruits have been started at various times at Pasadena, Redlands, Santa Ana, Riverside, and other places. An account of these has been given by Will.



(*Wilson: Jour. Ind. and Eng. Chem.*)

FIG. 20.—Flow sheet for manufacture of citric acid from lemons.

Work along similar lines in connection with Florida oranges has been published by McDermott and by Walker.

The United States Department of Agriculture became interested in the possibility of developing a citrus by-products industry in this country, and in 1907 sent E. M. Chace to Italy to study similar industries there.

Chace made a survey of the lemon industry in California in 1908, and as a result of his work the Department established the Citrus By-Products Laboratory in 1911 at Los Angeles.

The early work of this laboratory was done by H. S. Bailey and C. P. Wilson under the direction of Chace, who has been in charge of the laboratory since its beginning. The Citrus By-Products Laboratory secured accurate data on the methods applicable to the manufacture of citric acid, and the yield to be expected from lemons.

It must be remembered that the average haul by which citrus fruit raised in California reaches its market is about 2,500 miles. This precludes the shipment of anything but sound fruit of good appearance and keeping quality. There is necessarily left a large quantity of fruit that is not fit to pack and ship and is used in the manufacture of citric acid. This is culled out for reasons such as irregular shape, oversize, undersize, frost damage, heat damage, clipper cuts caused by careless picking, thorn pricks, wind scars, thrips marks, excessive scale, or any sort of mechanical injury or indication of decay or imperfection of any kind.

The steps in the process of manufacture of citric acid may be followed by means of Figure 20.

Extraction of juice.—All the citric acid in a lemon is contained in the juice, so that the separation of juice from the pulp may be considered the first step in the recovery of the acid.

The fruit is shoveled or dumped on to a broad belt conveyor and, if other products than acid are to be made, is graded to give the kind of fruit needed for such a product. Any lemon can be used to make citric acid, though, of course, the yield varies enormously from as low as 15 lbs. per ton from badly frozen lemons to 50 lbs. or more from the thin-skinned juicy "lemonettes." It is interesting to note that the effect of frost is to decrease the amount of juice in the fruit and also the percentage of acid which remains in the juice.

The fruit passes from the grading belt by way of a bucket elevator to a pair of cutting knives which tear the lemons coarsely and drop them into a set of wood roller crushers which thoroughly bruise the fruit and press out some of the juice. The crushed fruit drops into the hopper of a continuous screw press where most of the juice is removed. The continuous presses are similar to those used for pressing moisture, fat, or oils from fish, scraps, copra, vegetable seeds, etc.

From the first press the juice runs to the measuring tank, while the pulp is passed through a soaking box where it is saturated with water. From this the wet pulp is dumped into another continuous press and the juice goes to the same measuring tank as did the first juice. Pulp from the second press is elevated to the hopper of a third press, and receives a spray of water as it ascends the elevator. Juice from the third press serves as maceration water for the first soaking, while the pulp passes out and is used as fertilizer.

One ton of lemons contains on the average about 70 lbs. of total acid (calculated as crystallized citric acid). Using the extraction process described above, 85 per cent or more of this acid is obtained in the juice. Pure pressed lemon juice contains from 6 to 7 per cent citric acid, but on account of the dilution by maceration water the mixed juice obtained in factory practice averages about 4 per cent acid and contains about 5 to 5.5 per cent of total solids. The juice contains about 0.5 per cent of insoluble solids and is rather thick and pulpy. It is stored in wooden tanks of about 57,000 liters capacity, in which it is allowed to undergo fermentation for about four or five days in warm weather, or about ten days in cold weather. This fermentation seems to liquefy some of the mucilaginous, slimy constituents and to coagulate others. The sugars are completely removed. The chemistry of this change has not been worked out in detail, but it has been shown that the loss of citric acid by fermentation is negligible for the first few days. Factory experience has thoroughly demonstrated that fresh juice is very difficult to filter, while properly fermented juice filters easily and requires a minimum of filter-cel.

After proper fermentation, the juice is thoroughly agitated so as to reincorporate the pulp, which during fermentation has partly sunk to the bottom and partly risen to the top, leaving a clear layer in the middle. In earlier practice this middle portion was drawn off and used without filtration, and the pulp was washed by agitation with water and subsequent settling and decantation. This was a slow, wasteful process and left in the tanks a slimy voluminous residue that was very troublesome to handle. The present practice is to filter the whole juice after boiling with filter-cel. The well-mixed fermented juice is pumped into pine tanks 2.4 m. deep and 2.4 m. in diameter, equipped with copper heating coils and mechanical agitators. About 7,500 liters are handled at a charge, and enough filter-cel is added to clarify the juice on boiling. The operator adds the amount of filter-cel he deems necessary as indicated by experience, and brings the juice to a boil. A sample is withdrawn, and if it clears quickly by settling it is ready to filter. If it does not clear

readily, more filter-cel is added. The juice is again boiled and the test repeated until the juice is ready to filter. On the average, about 12 to 20 kilos of filter-cel are required for each 1,000 liters of juice.

Filtration is carried out by means of a copper-lined Sweetland press. A 30-in. wood plate and frame, open delivery, washing type press is used when greater capacity is necessary. The cake is thoroughly washed with hot water. The filter-cel may be recovered from the press cake by burning out the organic matter, or it may be used for the production of decolorizing carbon, as mentioned later.

Precipitation of calcium citrate.—The filtered juice is a brilliant, light amber liquid, averaging about 4 per cent acid. It is pumped into wooden tanks 2.4 m. in diameter by 1.5 m. high, with staves made of Oregon pine 7.6 cm. thick. Each tank is equipped with copper heating coil and mechanical agitator. A charge consists of about 3,700 liters of juice, and from a laboratory assay the amount of calcium required to precipitate the citric acid is calculated. In practice, sufficient hydrated lime of high purity is added to precipitate 90 per cent of the total acid, calculated as citric. Sufficient calcium carbonate is then added to neutralize the remaining 10 per cent of acid, and an excess of 7 kg. of calcium carbonate is added.

Experience has shown that if the juice is completely neutralized with calcium hydroxide, dark-colored compounds are formed. These compounds are difficult, if not impossible to wash out, and if not removed cause the liquor produced by the decomposition of the citrate to be very dark colored. This increases the difficulty of securing satisfactory crystals.

It has also been shown that, however great the excess of calcium carbonate added to the juice, there is always a small residual acidity, varying from 0.08 to 0.20 per cent, depending on the acidity of the original juice.

The resistance to corrosion of the copper coils placed in these tanks is noteworthy. For two years the tanks containing these coils were used for decomposing the citrate as well as precipitating it from the juice. The coils were therefore subjected to the action of liquors containing 10 to 20 per cent of citric acid and about 0.2 per cent of sulphuric acid for a great many days. During the last two years the tanks were used only for precipitating citrate. Apparently the coils were worn thin by the swirling calcium citrate, rather than by reaction between the copper and the acids.

The precipitated citrate is pumped into an iron plate-and-frame filter press and thoroughly washed with water at as near 100°C. as possible

(*From an old drawing in La Parfumerie Moderne*)

AN ORANGE GROVE IN JAMAICA.

(*La Parfumerie Moderne*)

AN ORANGE GROVE IN JAMAICA.

and then partly dried by blowing air through the cake. The citrate is dumped by way of a convenient chute directly into one of a series of pine tanks exactly like those used for precipitating the citrate, except that it has no heating coil.

Since the foregoing process was installed the Oliver continuous filters have been used for filtering the citrate and calcium sulphate precipitates.

Decomposition of citrate.—The citrate is suspended in dilute liquor obtained in washing the previous batch of gypsum and the amount of 66° Bé. sulphuric acid needed for the complete decomposition is added. The accuracy of this reaction is checked by filtering off a sample of the acid liquor, after thorough agitation for 30 minutes, and adding about 5 cc. of 45 per cent $CaCl_2$ solution to an equal volume of the filtered liquor. A faint precipitate of calcium sulphate should be noticeable after holding in the steam bath 5 minutes, indicating an excess of not more than 0.2 per cent sulphuric acid.

If too much sulphuric acid has been added it is necessary to add calcium citrate, the amount of which is determined by titration of a 10-c.c. sample, using phenolphthalein. A solution is then made up which is exactly 10 c.c. in volume and 10 per cent acid (as citric) in strength. As the liquor always contains over 10 per cent citric acid, this is a simple dilution. A standard solution is made containing 10 per cent citric acid, with a drop or two of ferric chloride solution added to give a depth of color equal to that of the solution to be tested. This is for the purpose of overcoming the difficulty in comparing depths of color which are not the same shade, and in practice has been very successful. Three drops of a 1:1000 solution of thymolsulphonephthalein and 1.5 c.c. 0.5 N sodium hydroxide are added to each solution. The pure citric acid solution assumes a characteristic yellow tint, while the sample containing sulphuric acid continues to display the red color due to the more highly ionized mineral acid. The latter is titrated with 0.5 N sodium hydroxide until the color matches that of the standard. The number of c.c. of 0.5 N alkali used in the last titration measures the excess of sulphuric acid, and hence the amount of calcium citrate which will be decomposed by it. This method has been found very practical in factory control work.

The decomposition of the citrate is usually completed in about three hours. The precipitated calcium sulphate is allowed to settle by gravity and the acid liquor drawn off. The precipitate is washed free from acid by decantation by the countercurrent principle, using a five-step cycle. The calcium sulphate residue is sun-dried and sold as fertilizer.

The acid liquor thus obtained is a light-amber solution containing about 12 to 15 per cent acid. It has a density of about 5° to 6° Bé., con-

tains about 0.12 per cent sulphuric acid, and has a purity of about 95 to 98 per cent.

$$\text{Purity} = \frac{\text{Per cent citric acid}}{\text{Per cent total acid as citric}}$$

Concentration of liquors.—The acid liquor from the decomposition of citrate is run into lead-lined open evaporators of about 17,000 liters capacity, equipped with lead steam coils, and in these evaporators the liquor is concentrated to 20° to 25° Bé. The liquor is kept at incipient boiling and never boiled hard. Agitation is maintained by air jets.

The concentration is completed in lead-lined vacuum pans of about 7,000 liters capacity. The concentrated liquor is delivered to the lead-lined crystallizers at 37° to 38° Bé. In three to five days a good crop of crystals is set, and the mother-liquor is drawn off and reboiled to produce another crop. The crystals are washed with cold water in a basket centrifugal. These centrifugals are standard 30-in. Weston type machines with bronze baskets. The inner lining is perforated sheet monel metal. The curbs are lined with lead.

The crude crystals are usually made by the granulation process in which the crystallizing liquor is kept in gentle agitation. A heavy crop of small crystals is thus produced.

The crude crystals are dissolved in warm water in a lead-lined tank by dumping them in a perforated lead basket suspended at the top of the tank, utilizing the well-known principle of the heavy solution going to the bottom while the most dilute solution is always at the surface where the crystals are continually dissolved.

Purification of crude acid.—The solution of crude acid is subjected to laboratory tests and purifying treatment prescribed and carried out under strict laboratory control.

The impurities to be removed are mainly: (1) organic color, (2) lead, (3) copper, tin, and antimony, (4) iron and nickel, (5) sulphuric acid and (6) calcium sulphate. All of these, except organic color, would appear in the ash on incineration, and their elimination automatically brings the ash to a negligible quantity.

Organic color.—Organic coloring matters are present in the raw juice, others are formed on heating and remain in the filtered juice, and to some extent are held by the citrate throughout the washing, and appear in the liquors. Some color is added by decomposition of the citric acid and organic impurities on heating in the evaporators. If not removed this color appears in the final crystals, bringing them below standard as to color and translucency.

In early work bone-black was used, but it had to be thoroughly washed with hydrochloric acid to remove the calcium phosphate, and then with water to remove the acid and soluble salts. This was expensive and laborious. Experiments with a number of decolorizing carbons soon showed the product known as filtchar 5B to be well suited to the work, and as compared with the bone-black to be cheaper in first cost and in operating cost. Since then another carbon has been applied very successfully.

Filtchar is added to the liquor in the proportion of about 1 to 2 per cent of the weight of the liquor, about 6,000 to 7,000 kilos of liquor being treated in a batch. The liquor is slowly warmed to about 70°C. Other corrective treatments are given at the same time. The completion of the decolorization is tested by filtering a sample of the liquor, treating a portion of the filtered liquor with more filtchar, heating and filtering, and comparing the color of the two filtrates. More filtchar is added or not, as indicated by this test. The final decolorized filtrate is a very pale-straw color in layers several inches deep, and appears practically water-white when seen through a ¾-inch test tube.

Lead.—A part of the lead is removed as sulphate by the sulphuric acid, a small amount of which is normally present in this liquor. The remainder of the lead is removed by precipitation as lead sulphide.

Copper, tin, and antimony.—Copper and tin are taken up from pipe lines, pumps, and valves, and antimony from the lead pipe lines and containers, which are alloyed with 2 to 4 per cent of antimony for stiffening. All three metals are precipitated as sulphides at the same time that the lead is removed.

Iron and nickel.—Iron enters the process as a slight impurity in the filter-cel, calcium hydroxide, calcium carbonate, and sulphuric acid, and is dissolved from certain parts of the presses and other machinery with which the liquor comes into contact.

Iron in the ferric state imparts a dirty brownish color to the acid crystals. In the ferrous state iron gives no noticeable color, but it slowly oxidizes and causes the crystals to become distinctly yellow on standing, even in closed containers. The color due to iron strikes the eye immediately and from a commercial point of view is one of the most undesirable defects the crystals can possess.

Nickel is taken up from monel metal containers and conducting lines, etc., and, though present in small amounts, it imparts a brownish tint to the crystals. In some cases there seems to be deposited a very fine

precipitate of oxide of nickel which gives the crystals a dirty grayish appearance and seriously modifies their translucency. Both iron and nickel appear in the ash and are also for that reason undesirable.

Both ferric iron and nickel form ferrocyanides which are practically insoluble in acid solutions. In the treatment with filtchar, etc., the liquor is constantly agitated by blowing air in at the bottom of the treating tank. This serves also to bring all or nearly all of the iron into the ferric condition so that it can be removed by precipitation as ferric-ferrocyanide.

Calcium ferrocyanide is admirably adapted to the removal of iron and nickel, as it is very soluble in water, precipitates both metals from the acid solution, and forms free citric acid and precipitates calcium sulphate, without the introduction of a new ion into the solution.

In using the ferrocyanide ion for the removal of iron and nickel, the liquor to be treated is sampled, and the sample filtered clear. To several 25-c.c. portions of the clear filtrate varying amounts of a 1 per cent solution of $Ca_2Fe(CN)_6 \cdot 12H_2O$ are added, together with about 0.5 gm. filtchar and the mixture is heated on the steam bath for 10 minutes, or just brought to a boil on a hot plate, and filtered.

If difficulty is experienced in securing a clear filtrate, a little filter-cel, which has been washed perfectly free from iron with hydrochloric acid and freed from acid by washing with distilled water, may be added before heating. This is very effective in holding the finely divided Prussian blue precipitate.

To all of the filtrates a drop of the 1 per cent solution of $Ca_2Fe(CN)_6$ is added. That sample which shows the least blue color, but in which there is nevertheless a visible blue color, is used as the basis of calculating the amount of $Ca_2Fe(CN)_4$ necessary to remove the iron and nickel from the batch of liquor in question.

Care must be taken that an excess of calcium ferrocyanide is not introduced into the liquor, as it passes through the vacuum pan and into the crystallizers. These are lined with monel metal and rapidly become coated with a film of nickel ferrocyanide, which appears in the crystals. In practice, enough calcium ferrocyanide solution is added to precipitate about 90 to 95 per cent of the iron and nickel present, since the 5 to 10 per cent left never appears in the crystals. As these metals become concentrated in the mother-liquors they are removed by subsequent treatment with the ferrocyanide.

It is to be noted that the other metals mentioned, notably copper, also form insoluble ferrocyanides. As calcium ferrocyanide is the most expensive reagent used in the treatment, the several steps naturally take

place in the order of the ascending costs of the reagents used: sulphuric acid, filtchar, hydrogen sulphide, and calcium ferrocyanide.

When the tests with filtchar, hydrogen sulphide and calcium ferrocyanide show that the treatment is complete, the liquor is filter-pressed and sent to the vacuum pan for final concentration.

Sulphuric acid.—At times sulphuric acid may accumulate in excess as the liquor is concentrated in the vacuum pan. If not removed, some of this sulphuric acid may appear in the finished crystals, even after thorough washing in the centrifugal. When a point is reached in the final boiling where the liquor has about two or three hours yet to remain in the pan, a test for free sulphuric acid is made. A sample of filtered liquor is mixed in a test tube with an equal volume of 45 per cent calcium chloride solution and heated in the steam bath for a minute or two. If more than a slight precipitate is obtained, an appropriate amount of calcium hydroxide in the form of a thin milk is drawn into the pan, throwing down the excess of sulphuric acid as calcium sulphate.

As the vacuum pan is lined with lead, the liquor always takes up more or less of this metal in the final cooking, and an extra precaution against this is taken by sucking into the pan about 20 liters of hydrogen sulphide water at the same time that the milk of lime is added. By the time the strike is withdrawn the sulphide has had ample time to precipitate the lead, and any excess has been boiled off.

Calcium sulphate.—Calcium sulphate is always present in greater or less amount in acid liquor, and more of it is formed by the combined treatments with sulphuric acid, calcium ferrocyanide, and calcium hydroxide. It seems a fair assumption that these liquors are always saturated with calcium sulphate, and as a matter of fact there is, at the end of any concentration of the liquor, a considerable amount of calcium sulphate suspended as a fine precipitate in the liquor. This is true of the final boiling in the vacuum pan, which rapidly becomes coated on the inside with a crust of the precipitated calcium sulphate.

The liquor is filtered immediately upon withdrawal from the pan to remove the calcium sulphate and all other insoluble matter. A wood plate-and-frame filter press is used, which is clothed not only with usual filter cloth but with heavy paper as well, to insure a brilliant filtrate.

Our experience has shown that this final filtration of the acid liquor is probably the most important single operation in the production of high-grade crystals. The precipitate removed is mainly calcium sulphate, but there are usually also some filtchar, iron and nickel ferrocyanides, and metallic sulphides, with sometimes small amounts of lead and calcium citrates. All of these precipitates, if not removed, appear in the crystals

and raise the ash above the limit of 0.5 per cent. Proper filtration removes them completely, giving a brilliantly light-straw or amber-colored liquor of about 36.6°Bé. at 50°C. This yields a good crop of clear, colorless crystals of pure citric acid.

Carbonized filter-cel.—If the liquor is difficult to filter, use is made of a carbonized filter-cel made at the filter plant. (Patent on this product has been applied for by the manufacturers.) It was noted that the raw juice is clarified by filtering after boiling with filter-cel. The press cake from this operation contains roughly equal amounts of filter-cel and organic matter from lemon pulp. When heated in closed retorts to a bright red heat the organic matter is subjected to destructive distillation, and very fine particles of carbon are deposited throughout the pores of the filter-cel. The carbonized filter-cel thus obtained is ground to a coarse powder. It is extremely light and porous, wets easily, and has a high decolorizing value when applied to citric acid liquors. It is particularly useful, however, in producing a porous, easily filterable press cake in the clarification of liquors which are slimy or viscous and clog the filter cloth rapidly, or which contain precipitates so fine that they pass through the cloth and paper. The carbonized filter-cel is far superior to the fresh unused filter-cel in this respect and is the best filter aid.

In using this carbonized filter-cel a small amount is added to the liquor to be filtered and thoroughly mixed with it, and the mixture is passed through the filter press. If the liquor shows a tendency to come through cloudy, the press cloths are precoated with carbonized filter-cel by mixing a few pounds with water and passing this through the filter press just before the liquor is sent through.

Crystallization.—The purified liquor is passed from the filter presses directly into the crystallizers.

These are monel-lined wooden tanks, 130 cm. × 435 cm. × 20 cm., with a capacity of about 1,150 liters. Other crystallizers of varnished wood, stoneware, porcelain, lead, and acid-proof enamel were tried. With wood, even with a good varnish, crystals stick to the surface, with eventual trouble from chips. Stoneware chips quite easily under the blows necessary to remove the crystals and acid-proof enamels are open to this same objection. Porcelain is too expensive to use in this country, though it is said to be employed on a large scale in Germany for similar work. Lead is objectionable because of the contamination of the crystals. Monel metal has been found quite satisfactory, although the liquors slowly take up both nickel and copper from it. It is hard and tough, the crystals are easily removed from it, and it is easy to keep clean and bright.

Where crystals are desired, the liquor is kept perfectly still for from three to five days, depending on the temperature of the surrounding atmosphere.

When granular acid (small crystals) is wanted, the liquor is kept in constant motion by a small air jet or mechanical agitator.

After crystallization is complete the liquor is drawn off and recooked in the vacuum pan, and refiltered. Further crops of crystals are removed as long as a satisfactory product is obtained.

In ordinary weather the acid crystals are simply washed in a basket centrifugal, and spread on a clean mixing floor to evaporate surface moisture. They are then graded for size by means of a monel metal screen, and packed for shipment. In wet weather it is necessary to use artificial means of drying and for this purpose a vacuum shelf dryer has been used.

Treatment of old liquor.—No citric acid liquor is ever discarded. When white liquors no longer yield crystals of U.S.P. quality, these liquors are classed as brown, and the crystals taken from them are dissolved and purified as indicated above. When brown liquors fail to yield a sufficient crop of crude crystals they are returned to the neutralizing tanks, diluted, and treated like fresh juice, recovering the acid as citrate of lime, which passes again into the regular process.

Quality of product.—The standard of purity for U.S.P. citric acid is quite high (*United States Pharmacopeia,* Vol. IX, No. 9) but the rigid laboratory control established when the first acid was produced has kept this factory free from complaints on the score of quality.

Use of metric system.—It may be interesting to note that from the start of actual production of citric acid, the metric system has been in use throughout the factory. Tanks are calibrated in liters per centimeter of depth, and the various chemicals are weighed in kilograms. There has been no difficulty in teaching ordinary laborers to use meter sticks and metric scales, and the saving in calculation in the laboratory has been enormous.

THE INDUSTRY IN THE SAN DIEGO DISTRICT

The San Diego district includes National City and San Diego. Its chief products are calcium citrate, lemon oil, coronet (lemon) flavoring extract, California melade (grapefruit juice), and citrus washing powder.

THE INDUSTRY IN THE SAN BERNARDINO DISTRICT

The San Bernardino district has its by-product industry located principally in four cities, namely: Corona, Ontario, Redlands, and Riverside.

The San Bernardino district produces citric acid, dried orange peel, lemon juice. Formerly orange wine was made.

THE INDUSTRY IN THE LOS ANGELES DISTRICT

The section of the citrus by-product industry centered about Los Angeles contains the following cities in which active commercial interests are located: On the north, San Gabriel, Alhambra, Pasadena, Altadena, Lamanda Park, and Monrovia, on the northeast, Pomona and Claremont, on the southeast, Anaheim, Placentia, and Santa Ana. The principal products of this district considering the number of firms manufacturing as a criterion are: (1) marmalade and jelly, (2) juices, (3) peel, (4) canned oranges, (5) calcium citrate, (6) wines and cordials (now discontinued). Miscellaneous products include a face cream, a shampoo, and a dentrifice.

FLORIDA

It was about the year 1884 that fair sized shipments of oranges began to move out of Florida. At the present time Polk County produces more citrus fruit than any other county in the state. Other large centralized fruit areas may be found (1) north of Polk County in Lake and Orange counties, (2) on the west coast in Pinellas and Manatee counties, and (3) on the east coast along the Indian River in Volusia Brevard, and St. Lucie counties. Many smaller citrus regions are found in various localities throughout the central and southern part of the state.[1]

Every year the citrus fruit growers of Florida as elsewhere suffer a considerable loss on account of the cull fruits which are not suitable for shipping. This loss may amount to as much as 10 per cent of the fruit coming into a packing-house.[2] The chief reasons for the existence of culls are superficial defects which in no way injure the value of the fruit for immediate consumption or for preservation. Since the local market cannot take care of this large amount of cull fruit, it is desirable there also to find methods of preserving or otherwise utilizing it.

The principal citrus fruits grown in Florida are oranges and grapefruit. In 1909 practically all the lemons and 74 per cent of the oranges of the United States were grown in California while nearly all the grapefruit over a million boxes was grown in Florida.

The manufacture of by-products in Florida is virtually confined to the making of marmalade and the preservation of grapefruit juice. Canning of grapefruit and bottling of grapefruit juice is done on a much larger scale than in California.

[1]C. R. Swinson and W. C. Funk, "Economic Aspects of Citrus-Fruit Growing in Polk County, Fla.," *U. S. D. A. Dept. Bull. No. 1435* (1926).

[2]*Florida Agricultural Experiment Station Bulletin No. 135* (1917), p. 131.

MEXICO

Oranges and bananas are the most important fruits grown in Mexico. In 1907, 83,814,000 lb. of oranges were produced. Over 90 per cent of these were shipped to the United States and Canada. During the fiscal year ending June 30, 1914, Mexico exported to the United States 6,194 lb. citrate of lime, and 99 lb. oil of lime. Citrus fruit production in Mexico is far below the potential output. For three years previous to 1926 no oranges have been shipped to Canada from the Montomorelos district of the state of Tomaulipas. It was planned to renew shipments beginning December, 1926. Refrigeration facilities have been installed in a number of steamers entering Tampico, and oranges will be shipped to Montreal via New York.

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CHAPTER XIII

THE INDUSTRY IN THE WEST INDIES AND NEIGHBORING ISLANDS

BRITISH WEST INDIES

Of the citrus by-products imported into the United States during the year ending June 30, 1914, 483,167 lb. of citrate of lime, 9,537 lb. oil of lime, 29,566 lb. oil of orange, and 39.2 per cent of the lemon, lime, and sour orange juice were received from the British West Indies. The orange oil came from Jamaica, the only place where it is produced.

ISLAND STATISTICS

Bahamas.—Small quantities of grapefruit and oranges are exported principally to the United States. By-products are likewise made in small quantities.

Jamaica.—Exports of grapefruit during the four years 1909–12 averaged $92,170 annually, of oranges $207,000, and of lime juice $19,258. During the year ending June 30, 1914, Jamaica exported to the United States 16.5 lb. oil of lime, 29,032 lb. oil of orange, and 4.2 per cent of the lemon, lime, and sour orange juice.

Leeward Islands.—The cultivation of limes is the principal fruit industry of the islands of this group, especially of Dominica, where the industry has attained its highest development. During the five years 1909–13 the lime crop of Dominica averaged 354,000 barrels yearly. The flour barrel used for measuring limes will average about 160 lb. of fruit. Calculated on this basis the average annual production was 56,640,000 lb. The average annual value of exports of limes and lime products during the years 1911–13 was $508,090. There were also exported from Dominica small quantities of oranges and orange oil. The lime crop for 1918–22, calculated in barrels (capacity 4.55 cubic feet) is recorded below:[1]

	Barrels
1918	318,000
1919	402,000
1920	369,000
1921	516,000
1922	400,000

[1] *Colonial Report No. 1195, Leeward Islands, 1922–23,* p. 15.

In the production of lime oil Montserrat ranks next to Dominica[1] and Antigua produces a smaller amount.

St. Lucia.—The cultivation of limes is increasing and seems likely to assume an important place in the economics of the island. Exports of limes and lime products increased from $1,411 in 1911 to $5,280 in 1912 and $15,220 in 1913. The production of lime oil, however, is less than that of Dominica and Montserrat.

Trinidad and Tobago.—The area used in the cultivation of limes and oranges in 1913–14 was 1,123 acres. The value of fruit exported has increased from $3,908 in 1905 to $57,396 in 1914. The lime oil industry here as in St. Lucia is not as great as that of Dominica and Montserrat. During the fiscal year ending June 30, 1914, Trinidad exported to the United States 99 lb. lime oil, and 0.9 per cent of the lemon, lime, and sour orange juice imported into the United States.

JAMAICAN ORANGE OIL

The earthquake that in 1908 laid Messina in ruins, and caused a set-back to the Sicilian production of essential oils, gave the first important impetus to the new orange oil industry in Jamaica. Until this time Sicily and southern Italy had been the chief, or practically the only sources of supply of the oils of orange and lemon.

The essential oils from Italy and Sicily were the standard in the world's market for many years. The manufacturer or syndicate of growers sold under well-known brands, the quality of the shipments being guaranteed by some analytical chemist. Until the loss through the Messina earthquake of large stocks of the oil, there was practically no sale for the West Indian product. There is quite a difference between the chemical constituents of the Jamaican and the standard Sicilian oil, and buyers were disinclined to change and thus risk altering the flavor or fragrance of their products. The adequacy of supply of the oil to which they were accustomed also militated against the Jamaican oils finding a market, except in small quantities at lower prices. Small quantities had thus been sold at prices as low as 75 cents per pound, which was less than the cost of production.

The rise in price of orange oil marked an opportunity for the orange producers of Jamaica who at the time were suffering from difficulties in marketing the crop under the high tariff on citrus fruits in the United States and the distance which separates Jamaica from the other worthwhile markets for so perishable and bulky a fruit.

Until this time, the production of oil from oranges had been largely experimental, and the experiments had been sufficient to indicate that

[1]See Table XL.

with increased prices, the local glut in production of the fruit and the abundance of cheap labor, the oil could be furnished in large quantities and a worth-while trade built up as soon as prejudice against a new source of supply had been overcome.

Method of production.—There is practically but one method in vogue for the production of orange oil in Jamaica. The machine used is essentially the same as that employed in Sicily. It consists of a copper disk 13 to 14 in. in diameter made of 16-oz. copper. In some cases a lighter copper is used. When the cage is turned over and stiffened with wire, the bottom of the bowl is fitted with a funnel ½ in. in diameter and 5 to 6 in. long with the bottom end closed. This copper disk is punched with a series of fine holes in concentric circles about $\frac{7}{16}$ in. apart. Copper tacks ½–⅝ in. in length are passed into the holes and soldered down with the heads flushed and the points protruding full length on the inside of the disk. The correct name for these machines as used in Sicily is écuelle; in Jamaica they are known as "rinders." These were formerly imported from London, but the native tinsmith has proved adept at making them. They now cost from 12*s.* to 15*s.* ($2.92 to $3.65) each, according to the gauge of copper used. A box is supplied with each machine provided with a wooden frame extension on which the under side of the bowl rests, the box itself providing a seat for the woman using the machine as well as affording a receptacle for the bottles of oil. The tendency has been to make the points too long, too sharp, and uneven. The "rinder" is held between the knees of the operator, seated, and with the open palm of the hand, the orange is rolled lightly over the points of the tacks. These prick the oil-bearing cells of the rind, or skin, of the orange, the oil oozing out and dripping down into the funnel-spout. The orange is ordinarily rolled until no further oil exudes. When the funnel is filled, the oil is poured through a piece of cloth into ordinary bottles, holding a quart or less. At this stage of the process, the oil is frequently found to contain some orange juice, and at times a mucilage. These foreign substances sometimes make it necessary to allow the oil to settle. Thereafter it is carefully drawn off and filtered into copper pots or pans, lined with pure tin, or occasionally into tin receptacles, and soldered. The rinding, though a simple operation, requires a certain care and skill. The length and evenness of the tacks in the rinder are important factors for the extraction of the oil without great waste. The tacks should prick the orange skin only. If they are uneven or too long and sharp, either all of the orange oil will not be extracted without increased labor, or the orange juice will ooze through and make extra filtering necessary, with its attendant waste.

Several attempts have been made in the past to introduce machinery to supplant the simple rinder now in use. These have met with but little success, as the rinding in Jamaica is done usually by women or children who work for small wages.

Very little oil can be taken from the skin of each orange so that the labor necessary to get even a pound of the oil is very considerable, and the quantity of oranges consumed in the process is very high. The trees are scattered, and so the gatherers, mostly girls and young boys, are sent out into the properties to gather the fruit and collect the oil on the spot. They soon get very expert. By this method, they only have to carry the oil to the manufacturers, the fruit being left on the ground.

In Jamaica, the oranges are not cultivated in groves as in Sicily and in the citrus growing districts of the United States, but the trees are scattered over the country in pastures and on hillsides. The orange oil is collected by gangs of girls and boys. The boys shake the oranges down and the girls sit below the trees and do the rinding. They can eat as many oranges as they like, of course, and after the rinding, the rest of the oranges are generally flung away, the cattle and pigs feeding upon them to a certain extent.

The laborers in Jamaica are paid from 30 to 60 cents "a bottle," according to the quantity of oranges available within certain limits of distance. The picking is done in the early hours of the day, and the rinding should be done immediately in order to get the greatest quantity of best-colored oil. The fruit should be picked when full grown, but not entirely ripe, as in the latter condition the oil has a deeper color and brings less price. If the picking and rinding is done during the heat of the day, the yield is less than when done at a lower temperature.

A local dealer states that 500 oranges will yield approximately 1 lb., 2 oz. of crude oil, or 1 lb. filtered, and that it takes eight hours to produce 1 lb. of crude oil. The quantity of oil obtainable depends upon the class and condition of the fruit. Oranges grown in a cool section of the island will yield more oil than the same quantity of fruit grown in a warm one.

Further costs and charges after rinding are those of collecting the oil from the different districts, its transportation to the seaports, the cost of the copper-tin-lined containers in which it is shipped and the steamship freight.

An unfortunate feature of the orange oil industry in Jamaica has been that, owing to the comparatively high prices offered, the oil is often adulterated with turpentine, kerosene oil, or cottonseed oil, or other fats. Such adulteration, however, can usually be detected by experienced

dealers, and a campaign has been inaugurated by the island authorities to stop the dishonest practice, and this is now reported to be in abeyance. If the adulterant is kerosene, it can usually be detected by smell immediately after removing the cork from the bottle. An effective method recommended is to "pour some of the oil in the palm of the hand, rub vigorously with both hands and then smell." The use of the polariscope for testing is advisable, and a hydrometer can also be used, but it is doubtful whether an accurate conclusion can be arrived at on the basis of specific gravity since a certain amount of turpentine can be added to the oil without density being greatly altered.

Method of shipment.—In the shipment of the oil to foreign markets, it should be protected from light and air, and it cannot be profitably put in tins or iron containers, nor in glass due to heavy freights and risk of breakage. The best, and now the most usual, practice is to pack the oil in specially made copper vessels, the inner surface of which has been carefully coated with tin.

At first, the oil was shipped from Jamaica in bottles, sometimes in demijohns, but this did not prove satisfactory. It made the freight expensive, the bottles were often broken, and the oil was apt to be injured and become cloudy from exposure to light.

The copper containers now used for the oil are of two shapes. The American ones are square like a kerosene tin. They are made of thin sheet copper the inside of which is covered with a thin coat of black tin. They have a capacity of 25 lb., and a small funnel aperture for filling. When filled this aperture is corked and covered with a thin disk of copper.

The other package is the Sicilian style. It has a round body with a half-round top and bottom. The sides and bottom are dovetailed together and brazed, forming one piece; this is carefully tin-coated inside. The top is fitted and joined with a heavy band of solder. The top is also fitted with a small funnel piece, and is closed and soldered like the American container. It is made to contain 25 lb. of oil, and the containers are packed two or four to the case. Occasionally Sicilian coppers are imported in the 12½ lb. size. The Sicilian coppers are considered better, stronger, and capable of withstanding rougher handling than the American square receptacles.

Testing and shipping by buyers and shippers.—The greatest care should be exercised before shipment to see that each bottle is filled with nothing but absolutely pure oil, and as a matter of fact the oil is generally filtered and tested and retested before being exported.

One shipper states that it is sought to have the product conform to the requirements of the *United States Pharmacopoeia* which provides

that the specific gravity should be between .842 and .846 and the optical rotation not below 95°.

Costs.—The sale price depends upon the combined demand from the consuming countries, principally the United States and the United Kingdom, and upon the available supply from the sources of production, principally Sicily and Jamaica.

Several years ago, a shortage in the American orange crop made it highly profitable to ship Jamaica oranges to the United States, despite the high import duty. Due to the shipment of the fruit itself in large quantities, the oil production fell off, and it became practically impossible to secure orange oil from Jamaica.

On the other hand, this is an article, of which the production may exceed the demand, and when the surplus fails to find buyers it must be held over till the following season. This happened a few years ago, and resulted virtually in the suspension of production for about twelve months.

During 1916 wholesale prices realized in New York, duty paid, for Jamaica oil varied from $1.75 to $2.50 per pound including the cost of the containers.

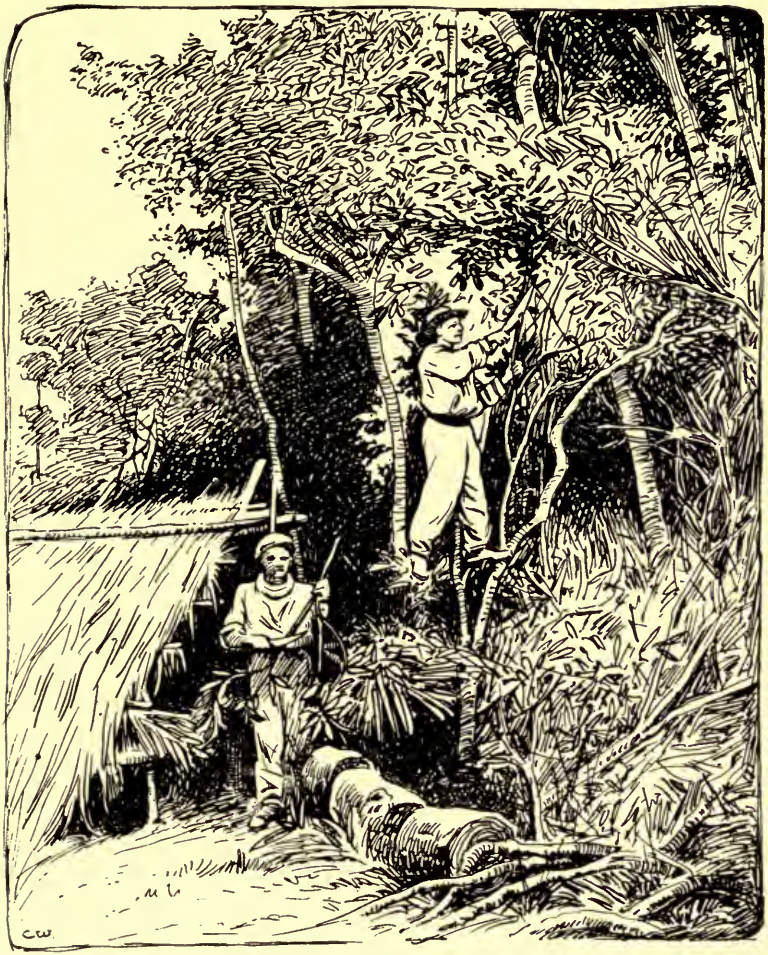
The following figures have been furnished by a principal producer in the interior of the island as representing the prices realized on a lot recently handled: 441 bottles sweet orange oil, each 1¼ lb. sold at $1.50 per pound; 557 bottles bitter orange oil, each 1¼ lb. sold at $1.25 per pound; 30 bottles of dregs not sold; total cost including pay of producer and delivery in Kingston, $1530,90, receipts $1641.54.

TABLE XLIX

Countries	1914		1915		1916	
	Packages*	Dollars	Packages	Dollars	Packages	Dollars
United States	1,033	57,586	1,276	55,496	1,953	119,634
United Kingdom	228	11,585	195	9,688	461	21,162
Canada	66	2,954	23	1,040	10	543
France	14	224	.....	.....	.....	.....
Germany	80	7,056	.....	.....	.....	.....
Belgium	19	302	.....	.....	.....	.....
Total	1,440	79,707	1,494	66,224	2,424	141,339

*The ordinary export package contains 50 lb. net.

The heaviest exports are recorded in 1916 when 121,200 pounds were shipped abroad of which 81 per cent was taken by the United States.



(*Bulletin of the Pan-American Union*)

GATHERING THE LEAVES OF THE BITTER ORANGE IN PARAGUAY.

Export prices show a variation of from 3 to 14 shillings ($0.73 to $3.41) a pound. During the three years—1914 to 1916 inclusive—the average price per pound was $1.06. In 1916 it was $1.17 a pound.

Exports.—Table XLIX shows figures taken from the *Blue Book* giving the volume of the export trade.

Supply and demand.—There is a general impression in Jamaica that if the industry of putting up orange oil here gets into many hands, and the shipping and marketing of it is independently done without co-operation, the trade will suffer. It is very necessary that the oil sent abroad be kept up to as high and uniform a standard as possible, for if unfair and inferior grades are shipped on the chance of finding a market, the result will be not only a probable loss to the individual shipper, but an indirect loss to all shippers of the product. It is not an article the consumption of which can be greatly stimulated by cheapness, and from the viewpoint of the producers, it would probably be more advantageous to market a limited production at good prices than a large production at low prices. The latter would lead to a price-cutting, careless production, and the shipping of a poor-class product to the foreign markets.

Bitter orange oil.—By far the greater amount of orange oil produced in Jamaica is sweet orange oil, but bitter orange oil is also produced in exactly the same way as the sweet oil though from the Seville or sour orange, and is not as valuable as the sweet oil. When the sweet orange oil is being sold at $1.75 per pound, the producer of the bitter oil counts himself fortunate if he succeeds in obtaining $1.25 per pound for his product. Both kinds are used also to flavor cakes and biscuits, and to some extent in the preparation of perfumes and essences.

LIME CULTIVATION

There are sweet and sour limes both confined to tropical and sub-tropical zones. Limes do not appear to flourish in Southern Europe nor in many other localities where oranges and lemons can be grown.

The sour lime (*C. Limetta*), although probably introduced into tropical America from the East Indies, has made its second home in this part of the world, where it is more generally cultivated. The tree is described as probably indigenous to the wild valleys of the outer Himalayas, and probably also of the mountain tracts of the Central Provinces and of Central India. The date of its introduction into the West Indies is not recorded, but it is supposed to have found its way to the English islands from Martinique.

Atwood, the historian of Dominica, in 1791, states: "The lemon and the lime trees bear also very aromatic scenting blossoms, and the fruit of both

is in great abundance, large and of excellent quality. Of these, the latter especially, great quantities are often sent in barrels to England and America. The neighboring English islands are likewise often supplied with them from this island, especially Antigua and Barbados."

Up to the time of Imray, in the middle of the nineteenth century, the lime was cultivated to but a slight extent in Dominica, and then for the fruit only. Experiments commenced by him in about 1852 showed that the cultivation of limes could be undertaken upon a commercial scale. About the same time, or a little later, a similar cultivation was commenced by Messrs. Sturge in the island of Montserrat.

Through the enterprising action of Messrs. Sturge, Montserrat soon became the headquarters of the lime industry in the West Indies, a position which in later years has been attained by Dominica.

It would appear that the future prospects of the lime industry of the West Indies are of a promising nature, and considerable interest has, of late, been awakened in this cultivation. The progress made in the industry in Montserrat, Dominica, and Jamaica has induced the planting of limes in British Guiana, Trinidad, Grenada, Garriacou, and St. Lucia.

Records show that lime products to the value of £280 were exported from Dominica in 1848, but that their value fell to £12 in 1857. In 1887, the value is given by (Kew Bulletin, August, 1888) as £8,561, while lime products from Montserrat were valued at £10,625. The total value of lime products exported from the island of Dominica, during the year 1906 was £55,174. The exports from Montserrat during the same period amounted to £6,883. Those from Jamaica were of the value of £3,909, and from Trinidad of £982.

The destructive hurricane that swept Montserrat in 1899 produced a falling off of lime products until 1908.

The rapid progress of the lime industry in Dominica is largely due to the assistance rendered by the Imperial Department of Agriculture, which has distributed at a small cost immense quantities of young lime trees from the Botanic Station. During the five years, 1902–6, over 150,000 ordinary lime plants have been distributed from the station, in addition to nearly 12,000 plants of the spineless variety. For the year ended March 31, 1907, about 70,000 lime plants were sent out. Of these 60,000 were of the ordinary kind, and 10,000 of the spineless variety. The agricultural school has also taken part in this work, and the pupils are thoroughly trained in the cultivation of limes.

For the year 1906–7, over 5,600 lime plants and 8 gal. of lime seeds were distributed from the Montserrat Botanic Station, and 37,000 plants from St. Lucia. The majority of the plants at St. Lucia were raised in the nurseries attached to the agricultural school.

As already shown, the lime industry of Dominica has made rapid progress in recent years. It received a serious setback from the attacks of scale insects in 1902 and 1903, when the exports dropped from £45,357 to £23,420. Valuable services were rendered by the Imperial Department of Agriculture in successfully checking these scale attacks, and the industry rapidly recovered. The exports of 1907 rose to a value of £77,407.

It is estimated that the total area under lime cultivation in 1912 was about 800 acres. The trees range in age from one to eleven years, and the plantations are on land situated at various altitudes, ranging from sea-level to about 1,000 ft., but the greater number of them are on alluvial soil.

Where the soil is light and naturally well drained and of sufficient depth, and the rainfall approximates to 80 in. per annum, the trees thrive and develop remarkably well, frequently beginning to produce fruits about the third or fourth year. On the other hand, where the soil is of the heavier type, although other conditions may be favorable, the development of the trees is not as rapid or uniform, and they appear to be more subject to root troubles and scale insect pests, particularly where attention has not been given to the proper drainage.

The first record in the *Blue Book* of the Colony, of lime products exported, occurred in the year 1906, when green limes to the value of £299 18*s.* 6*d.* and lime juice valued at £27 were shipped. The official records of lime exports are given in Table L.

TABLE L

Year	Green Limes, Value			Juice, Value			Total Value		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
1906.....	99	18	6	27	0	0	126	18	6
1907.....	111	4	6	81	0	0	192	4	6
1908.....	76	9	2	125	12	4	202	1	6
1909.....	31	13	0	297	9	0	328	13	0
1910.....	13	18	6	319	10	0	333	8	6
Total.....	333	3	8	850	2	4	1,183	6	0

THE LIME INDUSTRY IN ST. LUCIA

The first attempt to plant limes on a commercial scale in St. Lucia was made in the year 1901, on what was formerly a sugar estate, situated in a fertile valley, on the windward coast. During that year and the following 22,112 lime plants were supplied for this estate by the Agricultural Department. From this, the pioneer lime plantation, there was exported about five years later the first concentrated juice produced in the island.

Apparently, no further work in connection with planting in other parts of the island was done until 1905, when other landowners, doubtless encouraged by the promising results of the first venture, began seriously to contemplate planting their lands which appeared suitable for the crop. Since 1905, the demand for lime plants from the nurseries of the Agricultural Department has been steady, the total number distributed from

April, 1901, to March, 1911, being 257,907, representing an average annual distribution of 25,791 plants.

The progress of the industry may also be indicated by recounting the number of estates on which limes have been planted, as given by the plant distribution records of the Agricultural Department. From 1901 to 1905 there was only one estate on which limes were grown. In 1905 there were four; 1906, eleven; 1907, nineteen; 1908, twenty-four; 1909, thirty; 1910, forty-two. On some of these, however, the limes occupy only a few acres, while on others the acreage ranges from 30 to 70. It is estimated that the total area under limes at the beginning of 1911 approximated to 800 acres. The trees range in age from one to nine years.

An article in the *Agricultural News* of Barbados describes the condition of the lime industry in St. Lucia:

> As so often happens when new industries are started, a rush was made to plant up every available piece of land with limes, without considering the plant's requirements, or the capabilities of the land to be planted, with the inevitable result that, after a few years of lingering, whole areas died out, leaving isolated trees here and there to mark the former plantation.
>
> Apart from the waste of good material, time, money, and labor, the isolated and neglected trees became diseased and pest infested, and in such condition were a source of danger to neighboring lime plantations.
>
> It is safe to estimate that not one-half of the lime trees planted during the ten years previous to 1921 are alive today, or exports would be double their present figure. Nevertheless, the experience gained, although perhaps bitter in a few cases, has proved beneficial to the majority and limes are now planted with much more care and consideration than formerly.
>
> Notwithstanding these setbacks, the industry has made, and is still making, good and steady progress, and we can confidently look forward to a sound and profitable industry being permanently established.
>
> There are now seven modern factories working in St. Lucia island, where concentrated lime juice is prepared in steam-heated wooden vats, and the St. Lucia lime juice has made its individual marks known on the London market, where it commands the maximum prices.
>
> It is estimated that the present area under lime cultivation is about 4,000 acres.
>
> Lime plants must be protected from prevailing winds, and their roots must be kept free from stagnant water. Most of the St. Lucia lime plantations have been established on old and worn out sugar lands. During the four or five years that the plants have taken to reach the fruiting stage, very little food material has been taken from the soil, and for the following year or two, good crops are produced, and then the trees begin to decline, and the crops in some cases have reached the vanishing-point.

EXTRACTION OF LIME JUICE BY MILLING

The process of extracting lime juice from limes consists essentially of squeezing the fruit in some form of mill, usually of the three-roller

(*Bulletin of the Pan-American Union*)

BRANCH OF A BITTER ORANGE TREE.

type employed in the cane-sugar industry, possessing iron or granite rollers, and driven by hand, or by power. It is often supplemented by a cider press in which the squeezed skins are further subjected to pressure in order to extract a further quantity of juice. When the mills are of good type, however, the press is often dispensed with. At the present time ideas regarding the efficacy of the mills employed are generally decidedly vague.

The duty of a mill is usually stated in terms of gallons of juice expressed per barrel of limes. Such a statement leaves something to be desired. In the first place, the size of the barrel is liable to vary to some extent; in the second place, while it is true that the volume occupied by a given weight of limes will remain constant irrespective of size, provided that the limes are uniform in size, on the other hand, individual variations in the size of limes may induce appreciable variations in the quantity of limes measured. Moreover, the possibility must not be overlooked that the vessels in which the expressed juice is measured may sometimes be considerably in error, in the measurements which they record. Consequently, it is not surprising that there exists a considerable divergence of opinion as to the quantity of lime juice which it is possible to express from a barrel of limes by milling.

The problems connected with the extraction of lime juice as practiced in the West Indies at the present time are in many ways not dissimilar from those encountered in obtaining the juice from the sugar cane. In fact, in many cases, old cane mills have been adapted to the purpose of expressing lime juice, and so far as the actual extraction is concerned, the processes in the case of the two industries are identical.

In the case of the sugar cane it is well known that the juice content and fiber content of the cane, as also the saccharine richness of the juice, will depend very largely on the locality in which the cane is produced. Canes, grown under dry climatic conditions, usually contain less juice and more fiber than canes produced in localities with abundant water supply. Consequently the simple statement of the amount of juice expressed from a given bulk of canes does not afford an adequate measure of the efficacy of a cane mill, since this will vary with the juice content of the cane.

If the juice content of limes varies with the conditions under which the fruit is produced, in the same way, the mere expression "gallons of juice obtained per barrel of limes" can only have a local significance, even though the measurement of the quantities were strictly accurate.

With a view to ascertaining in what way the characteristics of the fruit vary according to the conditions under which it is produced, samples of

limes were obtained from different localities in Dominica, Montserrat, and Antigua by Tempanay and Weil.

In all, ten samples of limes were examined; in each case the average weight and volume of one fruit were first determined. Ten average fruits were then weighed and the juice gently expressed by a hand press; the juice was collected in a tared beaker and weighed separately. The acidity in terms of citric acid, as well as the specific gravity $\frac{30°}{16.6°}$ C. of the expressed juice was determined. On the skins, the acidity in terms of citric acid and the moisture content were determined. From these values the percentage of actual juice present in each sample of limes was calculated. In making this calculation the following formula was used:

$$\text{Juice content of lime} = x\ (100-x)\frac{a}{b}$$

Where $x =$ percentage by weight of juice extracted
$a =$ acid content of skins, per cent
$b =$ acid content of juice, per cent

TABLE LI

Estate	Average Weight of One Lime in Gms.	Average Volume of One Lime in c.c.	Juice Per Cent Extracted	Specific Gravity of Juice 27°/15°	Acidity of Juice in gm. per 100 c.c.	Moisture, Percentage in Lime Skins	Acidity, Percentage in Lime Skins	Juice, Percentage in Limes	Specific Gravity of One Fruit
Grove, Montserrat.....	61.2	60.6	49.4	1.0342	8.43 (8.15%)	77.3	1.92	61.3	1.099
Isles Bay, Montserrat....	51.4	....	50.8	1.0339	8.25 (7.99%)	79.2	1.79	61.8	.....
La Haut, Dominica.....	74.0	74.0	46.0	1.0322	7.19 (6.97%)	80.3	1.85	60.3	1.000
Lisdara, Dominica..... (ordinary)	71.0	70.0	50.6	1.0292	7.39 (7.19%)	83.9	1.53	61.1	1.013
Lisdara, Dominica ..... (spineless)	49.0	48.6	50.4	1.0309	8.25 (8.00%)	80.0	1.94	62.1	1.01
Canefield, Dominica	75.3	72.9	48.8	1.0346	8.25 (7.97%)	82.2	2.36	64.0	1.032
Botanic Station, Dominica	64.0	65.0	51.2	1.0327	7.45 (7.21%)	79.4	1.82	63.5	0.984
Dimsdale, Antigua.....	31.3	30.5	38.4	1.0409	8.67 (8.32%)	.....	3.19	62.0	1.026
O'Garas, Montserrat.....	66.6	66.4	46.2	1.0379	8.91 (8.59%)	.....	2.64	62.7	1.003

The acidity was determined by a modification of Prinsen Geerligs' method for the determination of sucrose in megass.

A quantity of skins amounting to 100 gm. is weighed into a tared beaker, 500 c.c. of distilled water is added, and the mixture boiled for twenty-five minutes. The beaker and contents are then cooled to ordinary temperature

and weighed. An amount of the solution measuring 100 c.c. is then delivered by means of a pipette into an evaporating basin, diluted with half its volume of water, and titrated against normal sodium hydroxide, using phenolphthalein as indicator.

From the weight of the beaker and contents after boiling are deducted the tare of the former and the weight of the skins employed (100 gm.). To this figure is added 80 to allow for dilution consequent on the moisture in the skins, and the result multiplied by the number of c.c. of normal sodium hydroxide used and by 0.00070. This gives the percentage of acid content of the skins in terms of citric acid.

Comparison of the values for the acidity as determined by the foregoing method with determinations on the same samples by the Soxhlet extraction method gave results in close agreement.

The results obtained are given in Table LI.

An examination of these results shows that the average weight and volume of a single fruit, as also the acidity of the juice, vary according to the locality in which the fruit is grown, the former characteristics varying directly and the latter inversely with the rainfall at the place of origin.

The percentage of juice contained in the fruit, however, varies relatively little, amounting approximately to 62 per cent of the total weight of the fruit. This result is of a distinctly unexpected character, since comparison with the sugar cane would tend to the belief that the juice content would be materially less in dry localities. It follows from this that measurement of the extraction of the juice, if accurately performed, will afford a reliable criterion of the efficacy of the milling in lime juice works.

As has already been said, however, the character of measurements of this description often leaves something to be desired; and it appeared that a useful purpose would be served if the endeavor was made to devise some simple system of mill control which could be used as a check on mill work at any time without involving alteration of conditions.

The value of the analysis of megass, in the control of cane mills, prompted the inquiry as to whether equally valuable results can be attained by the analysis of the squeezed lime skins left after the extraction of the juice. In view of the constancy of the juice content of whole limes, the determination of the amount of residual juice left in the squeezed skins appears to constitute a complete check on the efficacy of the milling at the time the sample was taken.

A considerable number of tests on these lines were performed on lime mills in Dominica, Montserrat, and Antigua, with a view to testing the value of the method of control and of ascertaining the efficacy of the mill work in the industry.

The method pursued was to take a sample of expressed skins and of the juice flowing from the mill at the same time; to determine the acidity of the juice and the acidity of the skins, and to calculate the juice lost in 100 lb. of the squeezed skins by means of the formula:

$$\text{juice lost per 100 lb. of squeezed skins} = \frac{\text{acidity of skins per cent}}{\text{acidity of juice in lb. per gal.}}$$

The results are given in Table LII.

TABLE LII

No. of Mill	No. of Test	Gallons of Juice Lost per 100 Lb. of Skins
Dominica 1	1	2.8
	2	2.8
	3	4.3
	5	2.6
	6	1.8
	7	2.4
	8	2.7
	9	3.3
	10	3.0
Montserrat 11	1	2.13
	2	1.99
	3	1.98
	4	2.29
	5	2.40
Antigua 12	1	3.15
	2	3.41

It will be seen that the figures for the amount of juice lost per 100 lb. of skins vary considerably. The best result is obtained in the case of No. 6—a Dominican mill—in which the loss amounted to 1.8 gal. of juice per 100 lb. of skins. This is a cane mill of modern construction, with pressure-regulating apparatus attached.

An interesting series of results is given in the case of mill No. 11, in which a series of tests on five separate occasions indicated losses varying between 1.98 and 2.40 gal. of juice per 100 lb. of skins, and averaging 2.16. The mill in question is one with granite rollers, driven by a 3½ horse-power oil engine. It appears from these results that the minimum amount of juice lost in this form of milling is somewhere in the region of 1.8 to 2.0 gal. of juice, per 100 lb. of skins. If we regard this minimum loss as unavoidable, the fact remains that in the majority of instances the avoidable loss in milling varies from ½ gal. to over 1 gal. of juice per 100 lb. of skins. If we assume that a barrel of limes gives 80 lb. of pressed skins—an assumption not very far from the truth—we find that the avoidable losses under existing

conditions of milling range in the majority of cases from 0.4 to 0.8 gal. of juice per barrel of limes.

It is not at present clear whether with systematic attention, it might not be possible to reduce the loss sustained under the present system of milling considerably below 1.8 gal. of juice per 100 lb. of skins. If it is not, it seems that the possibility of the maceration of skins with a view to the extraction of the residual juice might be worthy of consideration in the case of plants producing citrate of lime. It is doubtful how far it would be of value in the case of concentrated juice, by reason of the necessity for greatly increased evaporations in consequence of the dilution resulting from maceration.

It seems probable that, when raw juice is being prepared for the purpose of making lime-juice cordial, very high pressures are undesirable owing to the amount of pectic matter likely to be introduced into the juice in consequence. When, on the other hand, concentrated juice or citrate of lime is being manufactured, the condition of affairs is different, and it is suggested that careful attention to the milling of limes is likely to be productive of appreciable increases of yield.

The method described in the foregoing pages appears to offer a simple and effective check on the mill work accomplished, and may be recommended as likely to yield useful results, on trial.

LIME JUICE FOR CORDIALS AND FLAVORING

Lime juice intended for making cordials and for flavoring confections requires very careful preparation. The limes should be washed before being crushed in mills fitted with granite rollers. Only the first juice obtained by lightly crushing the fruit through the first rollers is used. The second juice and the press juice which are weaker in acid are used for concentrating.

The first mill juice is carefully strained and placed into puncheons when quite fresh. Formerly it was run into vats, and after settling the clear juice was placed in puncheons or hogsheads for export.

It is well known that raw juice carefully strained and placed in packages when quite fresh will keep in good condition for a considerable time, but if lime juice is exposed to the air it will gradually lose its acidity.

The raw-juice trade is in the hands of two or three firms and probably different methods are employed in each case.

LIME JUICE DISCOLORATION

The results of the preliminary work conducted by Hardy, in collaboration with F. H. S. Warneford, on the coloring matters of lime products,

suggests that the yellow and brown colors of these products are chiefly due to polyphenol compounds, not unlike certain of those described by the Louisiana workers[1] as occurring in cane juices and syrups. Without going into details, it is believed that fresh lime juice contains certain tannins or tannin-forming substances that yield colored products during the several stages of citric acid manufacture. Of particular interest are the indications already obtained in the laboratories that these colored products are chiefly due to oxidation. Especially noticeable is the rapid darkening which goes on when heated lime juice is neutralized by lime in the preparation of calcium citrate. A slight excess of lime in the liquor is accompanied by the appearance of a deep-brown color. A phenomenon of this sort due to oxidation is well known in the chemistry of tannins, and can easily be demonstrated by rendering alkaline a solution of some such compound as pyrogallol, and the addition of an alkali.

Lime juice, especially after keeping, on treatment with a solution of a ferric salt, yields a compound of red-brown color, which, in all probability is an iron-polyphenol compound. It has long been known that lime juice, extracted by mills possessing iron rollers, yields darker-colored products than does juice extracted by means of granite rollers. The effect is especially noticeable when the iron rollers have been allowed to rust. These facts are exactly paralleled by experience in sugar manufacture. Undoubtedly the acidic substances present in most of the plant saps that receive treatment in plant products factories are the agents primarily responsible for the formation of soluble ferric salts by their corrosive action on iron surfaces with which the saps come into contact, more particularly when those surfaces are covered with iron rust.

A boiling aqueous solution of citric acid attacks pure iron only slowly. Ferrous hydrogen citrate is formed. The same acid, however, attacks ferric hydroxide[2] (iron rust) quite readily, with the formation of ferric citrate.[3] This latter compound (although itself not deeply colored in dilute solution), being a soluble ferric salt, is capable of reacting with certain polyphenols, such as various tannins, to yield compounds of an intense green or brown color.

A. E. Collens reports an interesting analysis of a red-brown sediment taken from an iron vessel used in lime-juice concentration on a Dominica estate. Over 74 per cent of iron calculated as ferric oxide soluble in hydrochloric acid was found in this sediment, and was present in large quantity as ferric citrate.

It is self-evident from the foregoing considerations that the surfaces of all iron, vessels, pipes, machinery, etc., used in citric acid manufacture should be maintained in as clean a condition as possible, not only to minimize the production of deeply colored compounds but also to present the introduction into the citric acid liquors of objectionable quantities of iron, which are troublesome to remove in the preparation of high-grade crystals.

[1]See abstracts in *Agricultural News,* XX, No. 479 (September 4, 1920), 278; XIX, No. 483 (October 30, 1920), 340; and XIX, No. 487 (December 24, 1920), 406; XX, No. 507 (October 1, 1921), 308.

[2]Watt's *Dictionary of Chemistry.*

[3]Unpublished record of the Leeward Islands Laboratory, 1918.

The possibility of contamination of citric acid liquors by non-ferrous metals such as copper, lead, tin, and nickel, which are also used in the construction of various units of the citric acid plant, has received considerable attention. While the non-ferrous metals are relatively unimportant from the viewpoint of their being likely sources of coloration, their presence in citric acid crystals is highly undesirable, since much of the acid of best quality is intended eventually to enter into the composition of articles for human consumption.

A. E. Collens[1] has conducted an interesting investigation into the corrosive action of citric acid liquors on copper and brass under both factory and laboratory conditions. He found that strips of these materials immersed in fresh lime juice at air temperature in seven days lost respectively 0.167 and 0.110 per cent of their weight. In boiling lime juice the loss was appreciably greater. Concentrated juice did not differ remarkably from fresh juice in its corrosive action on copper and brass. Various West Indian planters have reported some slight action of citric acid liquors on non-ferrous metals in the factory, but have stated that the corrosive effect is not great. There appears to be no reason for the preference for copper over brass in the construction of pumps, evaporator-coils, etc., in the citric acid factory, especially if hard brass be used. Nevertheless, great attention is paid in modern citric acid factories, producing the highest grade crystals, to the removal of the merest traces of metals from the final liquors. Iron and nickel are removed by the use of calcium ferrocyanide; copper, lead, tin, and antimony, by the use of hydrogen sulphide.[2]

CITRATE OF LIME AND CONCENTRATED LIME JUICE

It is well known that lemon and lime juice constitute the raw material from which citric acid is manufactured; these juices usually contain from 10 to 15 oz. of citric acid per gallon, sometimes exceeding these limits from exceptional causes; if exported in this condition the cost for freight and packages would be exceedingly high, hence efforts are made to obtain the citric acid in a more concentrated form. Three methods of doing this have been suggested; concentration of the juice by boiling, the preparation of citrate of lime, and finally the preparation of citric acid in the country where the fruit is grown. The first two have for their object merely the production of raw material for the manufacturer in a concentrated form.

The preparation of concentrated lemon and lime juice is a very simple matter: The juice is passed through strainers to remove seeds and floating impurities, and is then boiled down to a proper degree of concentration, in copper or iron vessels, over open fires much in the same way that cane juice is evaporated in the old-fashioned muscovado process of sugar-making. When several evaporating vessels are placed in a series over the same fire, forming a battery, it is important to notice that the vessel or

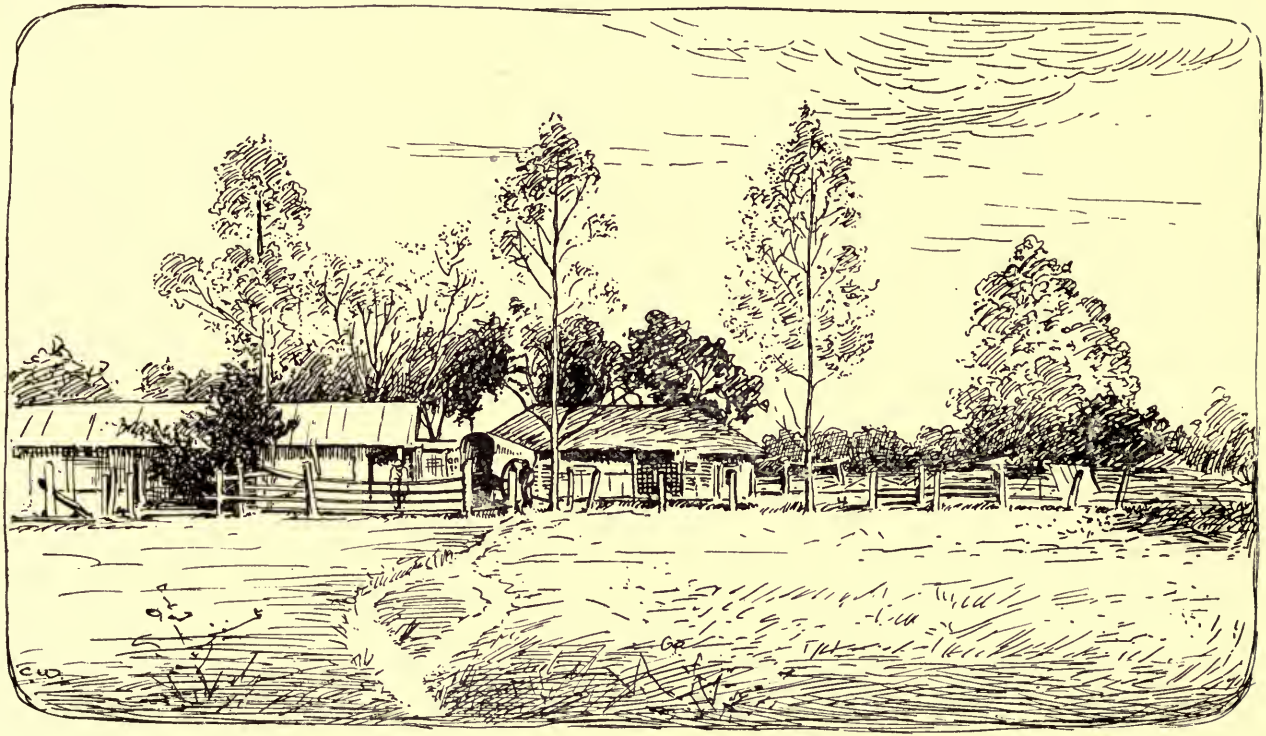
[1]Unpublished record of the Leeward Islands Laboratory, 1917.
[2]See pp. 253–55.

pan in which the juice is brought to its highest state of concentration is farthest from the fire; while that containing the fresh juice is over the fire itself; thus a battery for lime juice is hung in the reverse way to a sugar battery.

In concentrating lemon juice efforts are made to obtain a product containing 64 oz. of citric acid per gallon, this being regarded as the standard strength and a pipe of 108 gal. being regarded as a standard package; hence when the market price of concentrated juice is quoted at so much per pipe these standard quantities are assumed. In reality these quotations refer to an arbitrary quantity of 432 lb. of citric acid. In the production of concentrated lime juice in the West Indies it has been the practice to carry the concentration to a higher degree than this, so that concentrated lime juice usually contains upwards of 96 oz. per gallon; a good rule in practice is to endeavor to produce concentrated juice which will have a uniform specific gravity of about 1.300. In dealing with lime and lemon juices a particular form of hydrometer, known as a citrometer is frequently made use of, though its use is less common than formerly. Knowledge of the origin of its scale and the meaning of its indications appear to have been lost; from experiments which Sir F. Watts made some years ago he came to the conclusion that the instrument was so constructed that when placed in hot (boiling) lemon juice it will indicate the same degree as a Twaddel's hydrometer floating in the same juice in the cold. It is thus a useful instrument in the hands of the man in charge of the concentrating pans, for he can from time to time test the juice rapidly, in a hot condition, and arrest the boiling when the citrometer indicates the same degree which on a Twaddel's instrument will correspond to the specific gravity 1.33; this of course is 60°. Hence the rule for concentrating becomes: Carry on the concentration until the citrometer, when immersed in the juice at the boiling temperature, shows a density of 60°. The product thus obtained is a dark, nearly black, thick liquid.

It is often urged that there is very considerable loss of citric acid when juice is treated in this manner. When juice of good quality is treated, the loss is about 7 to 8 per cent of the original acid; when juice of poor quality is dealt with, this loss may reach 10 or 12 per cent, probably owing to the greater length of time required to concentrate the poorer juice to the required density. If concentration is carried beyond the point indicated the loss rapidly increases.

The method of concentrating lime juice favored on estates having an appreciable area of limes is that by steam in wooden vats. The first small factory erected in St. Lucia was of this type, and probably the



(*Bulletin of the Pan-American Union*)

A TYPICAL PARAGUAYAN OIL OF PETITGRAIN FACTORY.

first of its kind in the West Indies. The mill has granite rollers, is steam driven, and the juice is boiled in wooden vats, in the bottom of each of which is fitted a copper steam coil. Coils of heavily tinned copper, or preferably of block tin, are recommended as being most suitable, as they are less subject to the action of the acid, and consequently, a purer juice is obtained.

The modern factory on an estate of 60 or more acres of limes might be equipped to advantage, at the outset, with a plant that could readily be turned to account for the production of a pure product in the form of raw or concentrated juice, or citrate of lime, according to demand or state of the market.

A steam concentrating plant will make it possible to produce a superior class of concentrated juice, and admits of a change to citrate manufacture, as it can be readily adapted to the latter by the addition of one or more neutralizing vats plus facilities for drying the citrate. It might be possible to devise some form of steam drier for the citrate, and thus to utilize farther the steam-heating plant. Again, by substituting granite for iron rollers, and earthenware juice pump and pipe connections for metal ones, the purest raw juice for beverages could be turned out, as desired. The following are mentioned as possible advantages attending the concentration of juice by steam in conjunction with the use of non-metallic rollers and vat connections, in a well-arranged factory:

1. The loss of acid by combining with metal would be reduced to a minimum, and a purer sample of juice would be obtained.

2. There would be a smaller destruction of acid from excessive heat during concentration.

3. The possibility of reaching a higher degree of concentration without the serious destruction of acid which is unavoidable with the direct firing method.

4. The heating, boiling, frothing, and general handling of the hot juice in a well-arranged factory is likely to be under more perfect control than is possible under the old methods; and the works could be more efficiently controlled, and greater cleanliness maintained.

5. The heating value per unit of fuel used in the steam concentrating method, as compared with the similar value of that employed in direct firing is also a question worth attention when the two systems of manufacture are being compared.

MAC INTYRE'S EXPERIMENTS IN LIME JUICE CONCENTRATION

The experiments in lime juice concentration which are here described were carried out by MacIntyre for the purpose of ascertaining the loss of

acid occurring at various degrees of concentration so as to be in a position to judge whether the cost of steam-jacketed pans or other plant would be justified, and incidentally, to determine the point to which it is most economical to concentrate.

The experiments were carried out throughout the crop of 1910. The earlier experiments showed marked variations due probably to a variety of causes, but principally (1) to great variations in the quality of the fuel used, resulting in very unequal firing; (2) to the unsatisfactory method adopted for ascertaining the quantities of concentrated juice; and (3) to the impossibility during the pressure of crop of allowing sufficient time for the juice to cool thoroughly before being gauged. Toward the end of the crop it was possible to remedy these defects, and the result of these latter and more accurate experiments, only, are considered. Besides the ordinary boiling-house equipment not directly connected with the experiments, the plant consisted of the following:

1. A battery of three copper tayches, two of these being of 150 gal. each, and one of 220-gal. capacity, the last being farthest from the fire and being the copper from which the concentrated juice was "struck," 4 to 5 hogsheads being taken at each strike.

2. A package of 240-gal. capacity, accurately gauged for the measurement of the distilled juice used in the experiments. This was fitted with a lead pipe to conduct the juice direct to the first tayche.

3. A package of 300-gal. capacity, fitted with a hook gauge for measuring the concentrated juice.

During MacIntyre's earlier experiments a gauging rod was used for ascertaining the quantities of concentrated juice, but this method was found to be unreliable, and measurement by hook gauge was substituted.

As the great accuracy necessary in experiments of this nature is not easy to secure when measuring large quantities of liquid, a brief description of the hook gauge which he used may not be out of place here. His gauge was made somewhat in the form of a surveyor's leveling staff. To the bottom of the sliding rod was fixed a brass picture hook in such a way that the point of the hook, which was filed quite sharp, would point upward when the gauge was in position. The staff was securely fixed vertically in the measuring vat, the upper part, on which the scale was marked, projecting above the vat. To the upper end of the sliding rod (which was only half the height of the staff) was fixed a piece of sheet brass filed to a chisel edge on the upper side. The scale was carefully adjusted and marked on the staff. The method of using is as follows: When it is desired to measure any liquid in the package, the sliding rod is raised or lowered until the point of the hook just breaks the surface of the liquid and a reading is taken on the scale, on the line indicated by the edge of the brass plate. With this instrument it is possible to get very fine readings, but accuracy obviously depends on the correctness of the scale. To get the scale he first weighed a gallon of clear river water. Into an open oil drum set on a very sensitive scale he poured water to the weight of 5 gal. at a time. Each time the weight was reached the water was run into the vat situated on a lower floor, the rod adjusted, and a line marked on the staff. Precautions were taken to prevent spilling or much disturbance

of the surface of the liquid. In this way the 5-gal. divisions were obtained, the intermediate lines being subsequently put in with the aid of a graduated scale and a pair of dividers.

The scale was a fairly open one, and it was possible to read to ¼ gal. As the quantities to be measured were from 180 gal. upward, it will be seen that the error of measurement was reduced to a minimum. He subsequently tested the scale in other ways and found it accurate.

He used this gauge for ascertaining the capacity of the vat for measuring the distilled juice used in the experiments. By doing this he further insured accuracy, as even if the scales on the gauge did not represent the number of gallons indicated, the error would be repeated in the other measuring package—the volumes would be the same in both, and thus the ratios would be correct.

The juice having been distilled and subsided as usual, clear juice was run from the subsiders into a small tank from which it was pumped into the measuring vat, and a sample (50 c.c.) taken, after which the juice was run into the tayches as required. At the end of each day the aggregate sample was measured to secure accuracy of the tally, and tested for acid. Large quantities of juice were used for each experiment, in order as far as possible to reduce the experimental error.

Throughout the work, the juice was run into the copper immediately over the fire, and the strike taken from that farthest from the fire.[1] The coppers were always kept quite full[2] except when striking or when charging up to close an experiment, and always cooled down for an hour or more before taking a strike. Leakage around the tayches, which is sometimes considerable, did not occur during the progress of these experiments, nor was there any leakage from either of the measuring vats.

The strike was taken direct into the measuring vat and allowed to cool, when the quantity was ascertained and a sample taken after the juice had been thoroughly stirred. The tests for acid were made with the greatest care.

In these later experiments every effort was made to keep the fire as regular as possible and, as will be seen, the results are wonderfully uniform, having regard to the fact that the juice was boiled by direct fire, which is difficult to control.

Assuming a normal loss, the point of economical concentration would be about 9 to 1, which would give 97.6 oz. acid per gallon with a loss of 9.3 per cent. This would be presented by citrometer degree 54 at boiling temperature. It is difficult to fix the degree by citrometer with accuracy, as the cooling down for the strike greatly affects the reading. At 7 to 1 concentration the loss is 6.9 per cent; at 8 to 1 concentration the loss is 7.9 per cent; at 9 to 1 concentration the loss is 9.3 per cent; at 10 to 1 concentration the loss is 11.1

[1]MacIntyre emphasizes the importance of striking away from the fire. In a large number of boiling tests carried out by him some years ago when striking from the copper immediately over the fire the average loss at 10 to 1 concentration was 20.3 per cent. This was in addition to acid lost in filter sludge. The system has been discontinued in all estates in Dominica.

[2]Messrs. Ogston and Moore express the opinion that the loss of acid in concentration is very much greater when the surface level of the juice in the tayches is allowed to sink below flame level.

per cent. 1,000 gal. of juice containing 12 oz. of acid per gallon at 7 to 1 concentration would, on the basis of £18 10*s.* per pipe, represent a net value of £21 3*s.* 4*d.*, which he arrived at as follows:

1,000 gal. × 12 oz.	= 12,000		
Less loss 6.9 per cent	= 828	11,172	
Less 4½ per cent trade allowance[1]....		503	
		10,669 oz.	

$$\frac{10.669 \times £18\ 10s.}{6{,}912} = £28\ 11s.\ 1d.$$

Charges, etc. Discount 2½ per cent. commission 2½ per cent, brokerage 1 per cent. insurance ⅜ per cent, analysis, say ⅛ per cent. Total, 6½ per cent.....£1	17*s.*	1*d.*			
Freight on 143 gal. at 2½*d*.....	1	9	10		
Dock dues and rents, say, three farthings per gallon	8	11	3	15	10
Net proceeds on a/c sale			24	15	3
Local charges, 5½*d.* per gallon, made up of: package 3*d.* per gallon export duty 1½*d.* freight, boatage, and cartage 1*d.* per gallon			3	5	7
			£21	9	8

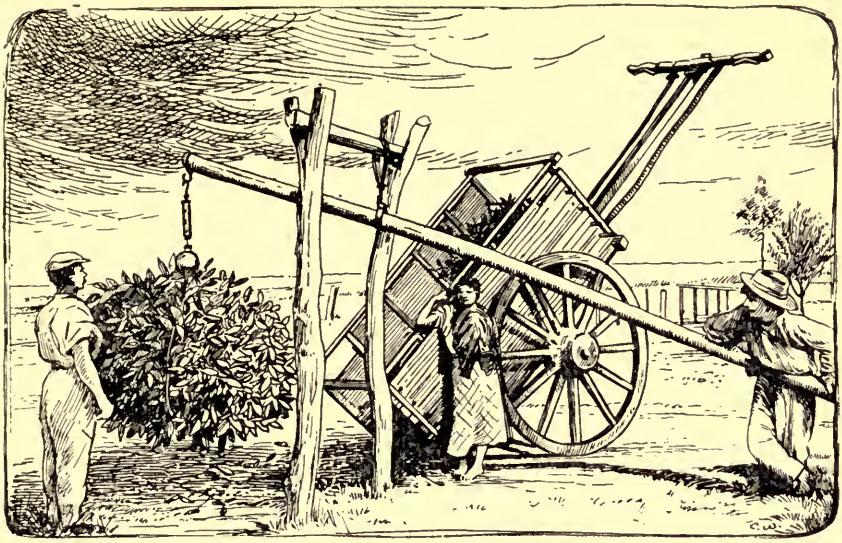
On the same basis 1,000 gallons of juice at

7 to 1 concentration would represent £21	9	8
8 to 1 concentration would represent 21	17	2
9 to 1 concentration would represent 21	19	2
10 to 1 concentration would represent 21	17	0

The average acidity of raw juice, which was tested from day to day throughout the crop, was 12.76 oz. per gallon. The foregoing calculations are based on the acidity of 12 oz., which would allow for acid removed in the sludge, for small mechanical losses occurring between storage tank and coppers, and for transit losses, leakage and soakage.

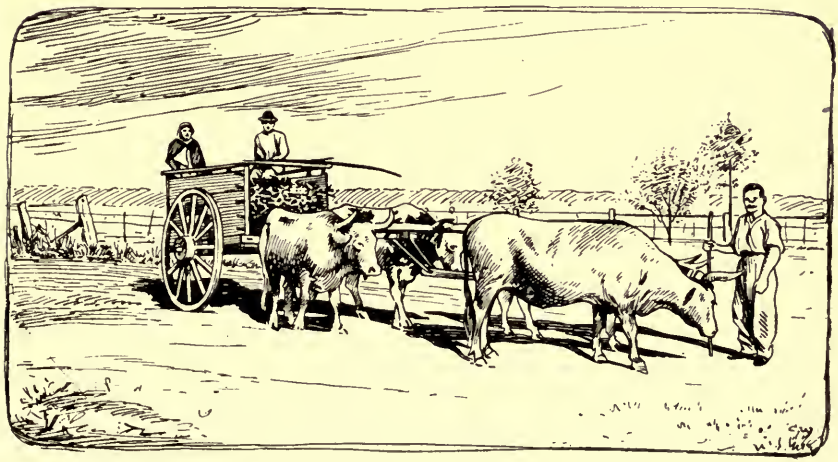
The correctness of the results obtained was strikingly shown by a comparison of the estimated value of the juice used in the experiments, as calculated on the basis of the foregoing figures, with the amount actually realized by the sale of the produce in London; the difference for the entire crop was under 1 per cent. It will be seen that the difference in value between concentrations at 8 to 1 and 9 to 1, and between those at 9 to 1 and

[1]A trade allowance of 4½ per cent is made by the analysts in all transactions relating to lime or lemon juice whether in the form of concentrated juice or citrate of lime, and is said to be for organic acids other than citric acid contained in the juice. This does not appear on the account sales.



(*Bulletin of the Pan-American Union*)

WEIGHING BITTER ORANGE LEAVES DELIVERED BY THE GATHERERS AT A PARAGUAYAN FACTORY.



(*Bulletin of the Pan-American Union*)

A LOAD OF BITTER ORANGE LEAVES ON ROAD TO AN OIL OF PETITGRAIN FACTORY.

10 to 1 amount to less than one-half of 1 per cent in either case—a difference which is well within the limit of variation in losses in open-fire concentration. In MacIntyre's earlier experiments it was clearly brought out that variations up to 2 per cent were to be expected between the results of concentrations with very high fire and those with slow fire. Under exceptional circumstances he recorded losses as low as 4 per cent at 7.5 to 1 concentration, and as low as 6.5 per cent at 9.5 to 1 concentration; but in both these cases, as the fire was kept very low, the concentration took nearly twice the time usually occupied in the process, and the juice was allowed to cool thoroughly in the copper before striking.

It follows from the foregoing that the precise point to which concentration is carried is not very material between the limits of 8 to 1 and 10 to 1 concentration, but there would be some advantage in the items of fuel and labor in favor of the lower degree of concentration. Above 10 to 1 the line of loss seems to rise very sharply. Throughout these experiments he took careful note of the acid lost in the sludge removed from the filter bags and ascertained that the loss was about 3 per cent of total acid when forty-eight hours had been allowed for thorough drainage of the bags, and from 3½ per cent to 4 per cent when only twenty-four hours had been allowed for draining. After thorough draining the stuff remaining in the bags is a thick, gummy mass, which contains a considerable quantity of acid. Repeated tests have shown that where the clear juice (distilled juice) has been tested 14.5 oz. per gallon, the sludge after thorough draining would test from 12 to 12.5 oz. It would be possible to recover most of this acid by washing over a finely perforated sheet-metal strainer, but most of the gum would then return to the juice in solution and probably have a prejudicial effect on the quality of the concentrated juice, besides adding appreciably to the quantity of liquid to be evaporated. It could only be satisfactorily dealt with if citrate were being made when neither of the foregoing objections would apply. The total loss of acid, then, under conditions of careful supervision, and concentrating to the most economical point, is about 13 per cent.

This on a crop of 10,000 barrels of limes (say, 85,000 gal.) would amount to about 240 lb., with lime juice at £18 10*s.* per pipe. It must be borne in mind, however, that in no process of manufacture is it possible entirely to eliminate loss. The loss of acid in steam concentration in jacketed pans is stated on good authority to be about 3 per cent at 9 to 1 concentration, to which must be added loss from filters or skimmings—the latter probably amounting to more than the loss from filters. Where filters are used, skimming becomes, to a great extent, unnecessary.

In making citrate of lime, the loss of acid, Messrs. Ogston and Moore say, should not exceed 2 per cent, and it is possible to recover most of the acid which is lost in filter sludge when concentrating. The chief advantages of citrate-making over the concentrated process are: (1) a minimum of loss in manufacture; (2) the relatively higher price usually obtained for the product;[1] (3) the great rapidity with which large quantities of juice can be

[1]This is not invariably the case. In October–November, 1911, citrate was selling at the price fixed by the Camera, £20 5*s.*, while, owing to the difficulty of getting forward supplies from Sicily, the price of concentrated lime juice advanced to £20 12*s.* 6*d.*

TABLE LIII*

LIME JUICE CONCENTRATION EXPERIMENTS

JUICE USED (DISTILLED)				CONCENTRATED JUICE		LOSS IN CONCENTRATION			DEGREE OF CONCENTRATION	CITROMETER DEGREE (APPROXIMATE)
Gallons	Test, Ounces per Gallon	Acid Content (Oz.)	Equivalent of Raw Juice at 12 Oz. per Gallon (In Gallons)	Gallons	Test, Ounces per Gallon	Acid Content (Oz.)	Ounces	Percentage of Total Acid		
1,680	14.16	23,788	1,982	275	80.4	22,110	1,678	7.0	7.2 to 1	45
1,680	14.25	23,940	1,995	246.25	89.1	21,940	2,000	8.4	8.1 to 1	50
1,680	13.89	23,335	1,945	221	96.4	21,304	2,031	9.3	8.8 to 1	54
1,680	14.00	23,520	1,960	206.5	103.3	21,332	2,188	10.6	9.5 to 1	58
1,680	13.7	23,016	1,918	195.75	105.1	20,753	2,443	11.6	9.8 to 1	58
1,680	13.57	22,797	1,900	188	107.2	20,153	2,644	11.4	10.1 to 1	60
1,680	14.34	24,091	2,008	197	108.3	21,335	2,756	13.2	10.2 to 1	60
1,690	13.62	22,282	1,907	175	113.5	19,862	3,020	8.7	10.9 to 1	62

*This is only approximate, for when the liquid is being cooled down, before striking, it is not possible to ascertain exactly at what point the strike is made.

dealt with; (4) saving of transit losses; (5) a saving in the cost of packages, against which, however, must be set the cost of chalk, and when working on a small scale, the somewhat greater cost of manufacture.

NOTE BY WATTS ON MAC INTYRE'S EXPERIMENTS IN LIME JUICE CONCENTRATION

The degree of concentration may be measured by the quantity of acid in the concentrated juice, and if we take into consideration the loss of acid experienced on concentrating to different degrees, we may correlate this with the rate of concentration in respect of the original juice.

In Table LIV the losses in concentration are taken at convenient approximations based on the results of MacIntyre's determinations, and there is shown (1) the degree of concentration in relation to the raw juice, on the basis (*a*) of 12 oz. and (*b*) of 14 oz. of acid per gallon; (2) the approximate loss of citric per cent; and (3) the approximate number of ounces of acid in a gallon of concentrated juice, after allowing for the distribution of acid in concentrating.

TABLE LIV

Degree of Concentration		Approximate Loss of Acid in Concentrating	Approximate Ounces of Acid per Gallon of Concentrated Juice
On Basis of 12 Oz. per Gallon	On Basis of 14 Oz. per Gallon		
7 1:1	6.0:1	7	78
8:1	6.8:1	8	88
9:1	7.7:1	9.5	98
10:1	8.6:1	11	107
11:1	9.4:1	13.5	114
12:1	10.3:1	16	121
12.5:1	10.7:1	18	123

From this latter it will be seen, for example, that a concentration which MacIntyre refers to as 10 to 1 on the basis of juice containing 12 oz. of acid per gallon is equal to 8.6 to 1 if the juice contains 14 oz. of acid per gallon —a point to be kept in mind in practice.

The calculations made by MacIntyre with regard to the effect of the concentration on the charges for packages, freight, duty, etc., are very important. It is obvious, however, that as some of the charges on shipment are based on the value of the juice, the net value of the product and the gains or losses consequent on concentratitng to various degrees will depend upon the market value. The calculations have, therefore, been worked out to show the net value of a quantity of concentrated juice resulting from the concentration of a quantity of raw juice equivalent to 12,000 oz. of acid when the value of concentrated juice is (*a*) £18 10*s*. and (*b*) £15 per pipe, charges deducted as the cost on packing and shipping being based on those given by MacIntyre.

From Table LV it is seen that the diminished cost of packages, freight, and other charges consequent on higher concentration offsets the loss of acid in such a way that the best financial results are obtained when the concentrated juice has an acid content of approximately 98 oz. per gallon when the market value is £18 10*s.* per pipe, or an acid content of approximately 107 oz. per gallon when the value is £15.

For all practical purposes, it appears sufficient to say that the best financial results are obtained, under the conditions laid down by MacIntyre, when the concentration is carried to approximately 100 oz. of acid per gallon.

Planters now test their own lime juice in the boiling-house and thereby save a considerable destruction of citric acid during concentration, by means of a citrometer or an ordinary specific gravity hydrometer. A description of a scale prepared by Dr. Francis Watts for use in ascertaining the strengths of solutions of citric acid and of lime juice by means of a hydrometer will be found in the *West Indian Bulletin* (V, 236–40), while a similar hydrometer method is described in the *Agricultural News* (VI, 149). The following extracts are taken from these articles:

In preparing concentrated lime juice the concentration should be carried on until a citrometer floating in the hot juice (at boiling heat) indicates a density of 60°.

TABLE LV

Degree of Concentration		Acid, Ounces per Gallon in Concentrated Juice	Net Value* after Concentration of 12,000 Ounces. When Value of 1 Pipe of Concentrated Juice Is					
Basis 12 Oz. per Gallon	Basis 14 Oz. per Gallon		£18	10	0	£15	0	0
7:1	6.0:1	78	29	9	2	16	7	3
8:1	6.8:1	88	21	16	6	16	16	10
9:1	7.7:1	98	21	18	1	16	19	10
10:1	8.6:1	107	21	17	7	17	1	0
11:1	9.4:1	114	21	9	11	16	16	0
12:1	10.3:2	121	21	0	11	19	9	10

* The slight differences between the figures in this column and those given by MacIntyre are due to the use of approximations for loss on concentrating given in Table LIV.

As the citrometer is an instrument but little known, difficulty has at times been experienced in procuring it. Its use, however, can be dispensed with, and an ordinary specific gravity hydrometer, the nature of which is universally understood, can be substituted, by making use of the fact that 60 on the citrometer is equivalent to 1.243 on a specific gravity hydrometer.

In this connection the following scale may be useful:

50° citrometer=1.202 specific gravity 54° citrometer=1.219 specific gravity
51° citrometer=1.207 specific gravity 55° citrometer=1.223 specific gravity
52° citrometer=1.211 specific gravity 56° citrometer=1.227 specific gravity
53° citrometer=1.215 specific gravity 57° citrometer=1.231 specific gravity

(*La Parfumerie Moderne*)

PURIFICATION OF PETITGRAIN OIL.

(*La Parfumerie Moderne*)

DISTILLATION OF PETITGRAIN OIL IN PARAGUAY.

58° citrometer=1.235 specific gravity 61° citrometer=1.248 specific gravity
59° citrometer=1.239 specific gravity 62° citrometer=1.256 specific gravity
60° citrometer=1.243 specific gravity 63° citrometer=1.260 specific gravity

Suitable specific gravity hydrometers graduated from 1.200 to 1.300 specific gravity can be obtained from makers of scientific instruments at a cost of about 2*s.* each.

Lime juice for concentration should, when leaving the mill, be carefully strained in order to remove all the seeds, before it is run into vats. From the vats it is run into the still to obtain the oil, and afterwards to the tayches to be concentrated.

It has lately been shown (*West Indian Bulletin,* VIII, 171) that lime juice, carefully strained, and then settled after distillation, has obtained a special market, and commands higher prices than ordinary concentrated juice. Every effort, therefore, should be made by planters to ship a high-class product.

The juice is shipped to New York or London in hogsheads of 52 gal., where it is tested and paid for according to the citric acid contents.

Buyers in London and New York pay for citric acid, and not for impurities in the juice. The presence of the latter causes great trouble to manufacturers of citric acid, and tends to bring prices down. Lime juice should, therefore, never be concentrated in iron tayches, as the iron combines with it and lowers the value of the product.

Concentrated juice testing 100 to 105 oz. per gallon made of well-strained and carefully settled lime juice is a black and heavy, but not a dense, liquid. When no care is taken to strain or settle the juice, the product is black, and as thick as molasses in the same degree of concentration.

CONCENTRATING LIME JUICE BY FREEZING[1]

An interesting piece of investigation, which may lead to results of practical importance, has been carried out by the Agricultural Department, in Dominica. During 1915–16, the Commissioner of Agriculture for the West Indies brought to the notice of the Dominica department an interesting article on the concentration of cider by freezing, which appeared in the *Year Book of the United States Department of Agriculture* for 1914. In this experiment it was shown that it was possible to concentrate cider by this process to one-fifth of its bulk without altering its properties as a beverage.

It was suggested that experiments be conducted to determine the behavior of raw lime juice when treated in a similar manner. It is ob-

[1]See also pp. 121–28.

vious that if raw lime juice, which is shipped for cordial purposes, could be concentrated without changing its essential properties, there would be a very considerable saving in freight, packages, and other charges.

The phenomenon that solids can be concentrated by freezing the liquid and removing a portion of the ice formed has been known for a long time, and in the reverse way this has often been made use of in obtaining drinkable water from sea-water. In this case it is the frozen portion which is saved, the amount of sodium chloride which it contains being so small as to make it moderately drinkable.

Numerous experiments were conducted during 1915–16 to ascertain how lime juice behaves on freezing, and the results obtained are discussed in the *Report of the Agricultural Department,* Dominica, for 1915–16.

The raw lime juice throughout the experiments was placed in a receptacle of block tin or a glass jar, which was packed round with a freezing mixture of salt and ice, which reaches a temperature of between —5° and —10°C. In a short time the juice becomes cooled to a temperature of between 1° and 2°C. Shortly after it will be found that ice has separated on the side of the jar, and on continuing the process this layer gradually thickens until later a core of juice remains and finally a solid mass is formed.

The sides of the receptacle are now warmed, and this solid mass slips out on to a basin where it is cut up with a knife into pieces of suitable size to enable their being readily placed inside the basket of the centrifugal machine.

The centrifugal is whirled round for a few minutes, and throughout these experiments the whole was melted in stages of known volumes.

The capacity of the centrifugal machine was such that only 500 c.c. of juice could be conveniently handled.

The general conclusions arrived at are given in the *Report,* and are as follows:

1. Raw lime juice when frozen and treated in the centrifugal can be concentrated without affecting its properties as a beverage.

2. If the juice is treated once only, the acid content may be increased from about 13 oz. per gallon to over 20 oz. per gallon.

3. If this be refrozen a juice containing 30 oz. per gallon can be obtained.

4. The low testing juices can be converted into citrate of lime, thus eliminating all losses excepting those of handling.

5. This process enables a very considerable saving to be made in freight, charges, and packages, amounting to between 40 and 60 per cent the actual amount depending on whether the juice is frozen once or twice.

HOLLINGS' METHOD OF CONCENTRATING LIME JUICE BY FREEZING

With reference to the note which appeared in the *Agricultural News* of November 18, 1916, on page 379, under the foregoing heading, de-

scribing the results of experiments with lime juice in Dominica, J. Spencer-Hollings gave an account of an interesting experiment made by him in connection with the same idea many years ago.

This apparatus employed in this experiment was one of Carres' ice machines. This proved a much more rapid and effective means of concentrating than by freezing only. The liquid to be concentrated in this machine is kept in vacuo by an air pump, and is also in direct communication with a chamber of sulphuric acid, which absorbs the vapor as soon as it is produced; and not only does it do this, but owing to the vacuum that is produced by the air pump, the liquid as it approaches freezing point assumes a condition of ebullition, which greatly accelerates the concentration. The resulting concentrated juice, not having been warmed, still retained the color and appearance of freshly squeezed lime juice, and as thick as the dark-brown product now made. When diluted with water, it had all the flavor of the fresh lime, and made an excellent beverage. Mr. Hollings states that after a lapse of at least two years he re-examined the cordial and found it still retained its characteristics.

CALCIUM CITRATE PREPARATION[1]

The preparation of citrate of lime is the first step in the manufacture of citric acid from lemon or lime juice. We are well aware that when the juice of the sugar cane is concentrated to a sufficient degree, the active principle, cane sugar, separates out in the form of crystals; the active principle of lemon or lime juice, citric acid, will not separate in a crystalline form when the juice is simply concentrated, owing to the presence in the juice of a large quantity of gummy or pectic impurities. In order to overcome this difficulty the citric acid is brought into combination with lime; the citrate of lime thus formed, being insoluble in water, can be separated from the gummy matters which remain dissolved. In order to effect this the juice is neutralized with chalk, the resulting citrate of lime is allowed to subside and finally separated by straining by means of linen or canvas. The resulting citrate may now be dried for shipment or be treated with sulphuric acid for the manufacture of citric acid.

Simple as the foregoing process appears, there are many practical difficulties, particularly in the preparation of the dried citrate for export.

In the first place the chalk employed must be of very fine quality, free from magnesium salts and from more than a trace of iron, alumina, and phosphates. Either of these impurities exercises a prejudicial action at one or another stage of the manufacturing process. Again, the chalk

[1]For detailed process, see pp. 250–51; see also pp. 149–50, 325–26.

must be of such a quality that it can be readily mixed into a cream with water; it must be free from lumps. In order to obtain chalk of proper quality English or French levigated whiting was for a long time imported into Italy and Sicily for the preparation of citrate of lime; for the West Indies, Watts believes suitable material is to be found closer at hand. The use of slaked lime suggests itself. This substance occurs in the form of a fine powder, easily mixed with water and can be obtained in a state of great purity. In default of other sources of supply, coral may be used and will yield lime containing a negligible amount of impurity. Analyses of several kinds of coral showed carbonate of lime 95.37 to 98.07 per cent, phosphate of lime .32 to .84 per cent, organic matter 1.93 to 3.79 per cent.

Should slaked lime be used, care must be taken not to neutralize the juice completely or impurities will be precipitated with the citrate, and these impurities will interfere with the subsequent manipulation and the production of citric acid; where slaked lime has to be employed it would appear desirable to complete the neutralization with chalk, using the lime only for the neutralization of the greater part of the acid.

In producing citrate of lime, the lime or lemon juice is placed in a suitable mixing vessel, large enough to prevent loss from overflow from the foaming effervescence which takes place when chalk is added. A sufficient quantity of chalk is made into a cream with water and the mixture poured cautiously as the acid is neutralized. There is some difficulty in ascertaining when the exact point of neutralization is arrived at, for in the presence of certain impurities, notably phosphate of iron, the juice remains acid although an excess of chalk may have been added. To ascertain how much chalk is to be used, it is best to proceed as follows: when the greater part of the chalk has been added, the mixture is well stirred and the effervescence is allowed to subside, a small quantity is then taken out and tested by the addition of a little of the mixture of chalk and water; if this produces an effervescence, more chalk must be added to the main quantity, proceeding cautiously and testing at intervals, until no effervescence is produced. A further test is now made: a little of the mixture is withdrawn and heated; as soon as bubbles of gas cease to be given off, a few drops of acid, fresh lime juice will answer, are added; this will produce a slight effervescence if chalk has been added in right amount, and a brisk effervescence if too much has been used. In the latter case, more juice must be added to the mixture and the process of testing repeated.

Having added the correct quantity of chalk it is desirable to heat the mixture for a few minutes nearly to the boiling-point, but actual boiling

is not necessary; this causes the citrate of lime to become crystalline and to subside rapidly in a condition in which it is easily manipulated.

In the earlier attempts to prepare this substance the heating at this state was omitted, the juice was neutralized, and the citrate of lime was separated from the cold liquor and dried. In consequence of this method of working, the finished citrate contained many impurities, it dried in the form of hard lumps or a powder full of hard knobs so that grinding had to be suggested, it was difficult to powder and when thrown into water it was wetted with difficulty so that the manufacturer had difficulty in acting upon it with sulphuric acid when converting it into citric acid. Owing to the presence of impurities the citrate often became dark on drying, and yielded a dark-colored liquor in the citric acid factory, a liquor which filtered with difficulty. All these features were very objectionable to the citric acid maker, and led him to prefer concentrated juice to citrate of lime as his raw material. Heating, by rendering the citrate crystalline, permits of its purification, and many of the impurities are removed with the water and can be easily washed away. It seems very important that heat should be used at this stage; it is probably due to its omission that the earlier experimenters with citrate of lime encountered so many difficulties.

As soon as the citrate is seen to become crystalline and to subside rapidly the heating is stopped, the citrate quickly settles, leaving a clear yellow liquid above; this liquid is poured off or syphoned off, as much water being removed as possible. Washing the citrate a few times with hot water is advantageous; this removed the gummy matters which cause the citrate to cake into lumps in drying and which may give rise to darkening in color and the subsequent production of dark and troublesome citric liquors in the manufacture of acid. The earlier samples of citrate contained so much impurity and were so difficult to manipulate that they found little favor with manufacturers.

The method of dealing with the citrate at the next stage of the process will depend entirely upon the scale upon which the manufacture is conducted. When the operation is conducted on a small experimental scale, the citrate may be thrown upon a stout cloth supported on a sieve or strainer; as soon as the water has drained away, the residue is tied or folded securely in the cloth and submitted to pressure, to remove as much water as can be thus got rid of.

When a large quantity of citrate is made, a filter such as is used in citric acid works may be employed. This consists of a deal floor with boards round the edge; the floor has 1-in. splines nailed on 1-in. apart, and canvas (36 in. "forfar") is stretched on the splines; a convenient

size is 16 ft. × 12 ft. × 1 ft. deep. It should be slightly tilted, and exit holes provided (Grosjean). The citrate is allowed to drain upon the filter; when draining ceases the substance is put into canvas bags and submitted to pressure.

On a large scale it will be found more convenient to use filter presses; by their use the combined operations of filtering and pressing can be expeditiously performed, a great saving of time and labor can be thus effected, while the factory can be rendered much more compact owing to the small area occupied by the filter presses as compared with the space required for filters and the presses for the bags.

After as much water as possible has been pressed from the citrate by whatever process is adopted, it has to be dried. This part of the process demands great care, and is attended by considerable risk of loss; there is great tendency on the part of the citrate, when in a damp state, to ferment; as a result of this fermentation, the citric acid is destroyed and carbonate of lime, the original chalk from which the manufacture started, is left; there is little to indicate to the eye that this fermentive change is taking place, so that an unskilled or careless operator may find his finished product to contain no citrate of lime at all, but to consist entirely of chalk. To avoid this risk of loss it is only necessary that the citrate of lime should be brought quickly into some form of drying apparatus where a temperature of from 150° to 200°F. (66° to 93°C.) can be maintained, while at the same time there is a free circulation of air through the drying chamber in order to carry away the moisture. For a long time the difficulty of obtaining a satisfactory and efficient drying apparatus was a great stumbling-block; the problem of drying the citrate of lime is very similar in its nature to that of drying fruit, so that a good fruit drier will answer well for experimental purposes, while larger forms of apparatus, worked upon the same principles, can be constructed for use where the manufacture is conducted on a large scale. Where much work is to be done it would appear desirable to have several sets of drying apparatus, so that one lot of material may be thoroughly dried before it becomes necessary to introduce fresh, wet citrate into the same apparatus. Any form of apparatus in which the temperature can be maintained at from 150° to 200°F. or even somewhat higher, while at the same time permitting sufficient ventilation to remove the moisture rapidly, will prove efficient. It is important to lay stress on the ventilation. As has been stated, the proper drying of the citrate is of paramount importance; should it remain damp, or in any way become damp from careless handling, or careless storing, fermentation will speedily spoil the product.

Warrington and Grosjean made an investigation of the amount of water remaining in citrate of lime dried at 212°F. (100°C.). They found this to range from 5.90 to 7.68 per cent. This exists as water of crystallization; when dried at 392°F. (200°C.) the substance contained no water. Fermentation readily takes place if more than 12 per cent of water is present; there is, however, no danger of fermentation as soon as the proportion of water has been reduced to 10 per cent but it is desirable to continue the drying until less than that amount exists; if the temperature of the drying apparatus cannot be raised above 212°F. the product, as shown by the investigations just referred to, may contain over 7 per cent of water; if, however, the drying can be finished at a higher temperature, say from 248° to 302°F. (120°–150°C.) the proportion of water may be reduced to below 5 per cent. Efforts should be made to secure this thorough drying.

When prepared in the manner described, citrate of lime is a white powder free from hard lumps; when thrown into water it is easily wetted and is readily diffused through the liquid on stirring. If kept in a dry place it will remain good indefinitely. For shipment it should be tightly packed in paper-lined barrels. It should contain over 60 per cent of citric acid.

Warrington states that the best sample of commercial citrate he has met with contained 72 per cent of citric acid, and this is about the highest percentage that can be reached when the citrate contains no excess of chalk and has been thoroughly dried.

SALABILITY OF CITRATE AND JUICE

Citrate of lime is bought and sold on the same basis as concentrated lemon and lime juice, namely on the basis of citric acid contained. Quotations are made for the same arbitrary quantity as in the case of concentrated juice. In this case the standard is the cask of 675 lb. of citrate, containing 64 per cent of citric acid, this being equal to 432 lb. of citric acid. As to price, citrate sells at about the same rate as concentrated juice, realizing a little more, sometimes a little less, than that article.

From the point of view of the manufacturer of citric acid, citrate of lime possesses some advantages over concentrated juice. It can be stored without loss, while juice is liable to leak from the casks; the first stage of the manufacture of the acid has been already completed and the manufacturer can dispense with the neutralizing vats and the filters; thus there is much economy of space and labor. Finally, owing to the fact that citrate of lime is white, while concentrated juice is black from the charring action of the heat used in its production, the resulting citric

liquors obtained from citrate are a better color, yielding whiter crystals of citric acid, thus reducing the operations of refining the citric and saving both labor and material.

Possessing these advantages it seems probable that citrate of lime and citric acid will ultimately displace concentrated juice, provided that an article thoroughly suited to manufacturers' requirements is produced; as competition becomes keener in the production of raw material—and this is likely to ensue from the attention being given to tropical products and the difficulty experienced in finding new and profitable ones—there will arise competition between these two forms of raw material, when the preference which the manufacturer of citric acid will give to well-prepared citrate will no doubt enhance its value in comparison with concentrated juice. Hitherto the production of citrate of lime has been relatively small so that competition between the two forms of raw material can hardly be said to exist.

It has been proposed to undertake the manufacture of the citric acid itself in the countries where the juice is produced; this offers many obvious advantages, but at the same time is beset by some difficulties. The chief difficulty would appear to be a trading one; the manufacture of citric acid is in the hands of a few firms against whose interests small manufacturers could not contend, so that the probability of citric acid being made in the countries producing the raw materials seems remote unless the venture is undertaken on a large scale.

In Dominica it is customary to carry the concentration of the lime juice to a higher degree than 64 oz. per gallon. Concentrated juice from this island ranges in strength from 105 to 120 oz. per gallon, or even higher. That such a degree of concentration is attainable without considerable loss is due to the fact that juice of good quality is used for concentration; on many estates in Dominica the whole of the juice obtained is concentrated, whereas in some places the finer qualities are exported as raw juice while the inferior ones alone are concentrated. These finer juices will contain larger proportions of acid in relation to the other soluble matters present, and therefore, when concentrated to a definite specific gravity, will contain more acid than concentrated juice derived from raw juice of lower grade.

Buyers point out some defects of West Indian concentrated juice; one is the presence, at times, of considerable quantities of pulpy matter, seeds, and other impurities; another defect lies in the presence in some samples of noticeable quantities of iron.

Some buyers stated that they were of the opinion better prices, both for concentrated juice and for citrate, may be obtained if the West

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HARVESTING CITRONS IN CORSICA.

(*La Parfumerie Moderne*)

SORTING CITRONS IN CORSICA.

Indian trade were better organized, their experience being that small lots of concentrated juice appeared on the market at somewhat irregular times, so that buyers were unable to be on the lookout for, or to depend on, the arrival of West Indian supplies. These lots often arrived when there was no particular demand and after buyers had made their contracts; they, therefore, sold with difficulty and at lower prices. This may be remedied by better organization, by such methods as making contracts beforehand, by the careful use of marks and brands, by intimations in trade journals of the conditions of crops, their probable quantity, and the probable times of arrival in the market.

It is possible to make contracts for the delivery at specified dates of lots equal in size to about 25 casks and upward of concentrated juice as shipped from the Leeward Islands. These contracts are made from about January to April. It is interesting to note that in 1901 contracts were made for Italian and Sicilian supplies at about £17 to £19 per pipe, while later in the year the market had fallen to about £13. It seems, therefore, highly probable that better prices may ultimately be obtained for West Indian juice by a closer acquaintance with British market conditions and by the preparation of high-class products in connection with known marks and brands.

Citrate must not contain more than 2 per cent of free chalk, a penalty being imposed if this amount is exceeded.

As regards price, citric acid, whether in the form of concentrated juice or of citrate of lime, has practically the same market value. Citrate of lime is quoted in terms of the standard acid; a standard cask therefore contains 430½ lb. of acid. Concentrated juice is quoted in terms of the pipe of 108 gal. containing 64 oz. of citric acid per gallon, being equivalent to 432 lb. of acid; the quantities are practically identical. At present these two commodities command approximately equal prices, sometimes one, sometimes the other, having a slight advantage. Import duty is imposed on citrate entering France while concentrated juice is admitted free, in consequence of which concentrated juice may at times command a slightly higher price in European markets.[1]

During 1899 prices ranged from £13 to £20 per pipe or cask; during 1900 prices ranged from £13 to £17 per pipe or cask; during 1901 prices ranged from £13 to £19 per pipe or cask.[2]

Under these circumstances the West Indian producer, in deciding which article he shall make, must ascertain the difference in cost of production and whether the buyers are likely, at an early date, to prefer one

[1] See pp. 352, 353, 362–66.

[2] See pp. 352, 353, 356, 362, 366.

article to the other. Citrate is more expensive in preparation than concentrated juice, the cost of erecting steam-heating apparatus and drying chambers and of importing and transporting lime or chalk will more than counterbalance the saving of fuel, the reduction in cost of packages, and the saving of acid destroyed in the process of concentration. Nevertheless we have the evidence afforded by Italy and Sicily, the principal sources of supply where the production of citrate is making steady headway and where the process is found to be better and cheaper than simple concentration. The exports of both articles from Messina and Catania have been as follows:

December 1, 1899, to September 30, 1901, concentrated juice	1,671 pipes
Citrate of lime 635½ tons	2,085 pipes
Total	3,756 pipes
December 1, 1900, to September 30, 1901, concentrated juice	549 pipes
Citrate of lime 590½ tons	1,969 pipes
Total	2,518 pipes

The manufacturer of citric acid will ultimately show a decided preference for citrate of lime and this as soon as the manufacture of citrate in Italy and Sicily is placed upon a sure footing so that citrate of uniform and dependable quality comes steadily to market; when that point is reached citrate will begin to command higher prices than concentrated juice. West Indian producers will then have to produce citrate if they wish to obtain the best prices for their goods. This time may not be far distant, for the experiments of the last thirty years have removed most of the difficulties which were encountered, while during most of the last ten years the advance has been very marked on the commercial side.

Table LVI is added in order to facilitate calculations dealing with the acidity of raw juice. In some places it is customary to speak in terms of ounces of citric acid per gallon of juice, in others in terms of grains per ounce.

WEST INDIAN LIME OILS EXPRESSED AND DISTILLED

Origin and production.—The lime, like the fruits of other members of the citrus family, contains essential oil in vacuoles situated immediately beneath the outer rind or skin. Two classes of lime oils are at present known to commerce: (1) the hand-expressed oil or otto of limes; (2) the distilled oil.

Hand-expressed oil is obtained by rapidly rotating the fruit around

[1]See p. 12.

the interior of a copper bowl, termed an écuelle pan, the inner surface of which is covered with projecting brass points.[1] The oil cells become punctured and the oil, mixed with a certain amount of watery fluid from the skins, runs down into a little well at the bottom of the pan; it is subsequently separated from the underlying layer of watery fluid, filtered, and stored in vessels ready for export.

The distilled oil, on the other hand, is obtained by performing the first stage of the evaporation of raw lime juice, in the manufacture of concentrated juice, in a copper still and condensing the distillation product; the steam passing over carries with it the more volatile portion of the oil, which is collected in a form of the well-known Florentine flask. In the case of estates which ship raw juice, the scum that collects on the juice in the settling vats is alone distilled.

TABLE LVI

SHOWING THE QUANTITY OF CITRIC ACID IN GRAINS PER OUNCE, EQUIVALENT TO OUNCES PER GALLON, AND VICE VERSA

Ounces per Gallon	Grains per Ounce	Grains per Ounce	Ounces per Gallon
8	21.875	20	7.314
8.5	23.242	22	8.045
9	24.609	24	8.777
9.5	25.966	26	9.508
10	27.344	28	10.239
10.5	28.711	30	10.971
11	30.078	32	11.702
11.5	31.445	34	12.434
12	32.813	36	13.165
12.5	34.180	38	13.897
13	35.547	40	14.628
13.5	36.914	42	15.359
14	38.282	44	16.091
15	41.016	48	17.554
15.5	42.383	50	18.285
16	43.750	.....	.....
16.5	45.117	.....	.....
17	46.484	.....	.....
17.5	47.851	.....	.....
18	49.219	.....	.....

Difference for ¼ oz. per gallon = .683 grains per ounce.

Difference for 1 grain per ounce = .365 oz. per gallon.

The oil is exported in either copper or tin vessels which are packed in boxes. It costs less to produce than hand-pressed oil, but commands a lower price.

Stills fitted with steam coils are the best, but it is only in a very few cases that steam is available on estates.

The yield of oil by distillation is from 3 to 5 oz. per barrel of limes, or taking 80 barrels of fruit to make 1 hogshead of concentrated juice,

from 15 to 25 lb. per hogshead, according to locality and conditions of moisture. A gallon of distilled oil weighs 9 lb.

The yield of oil varies according to conditions of moisture. In localities where the annual rainfall is from 60 to 100 in., the citric acid content of the juice of the fruit is high, and the yield of oil from the rind of the fruit low. Where the rainfall is high—say, from 130 to 200 in.—the citric acid content is low, and the yield of oil high.

It may be pointed out that the distilled oil is derived from the rind in the same way as the hand-expressed oil, the oil cells becoming ruptured in the process of milling, and the oil running down with the juice.

It is characteristic of distilled oils, in contrast to the écuelled product, that they possess a somewhat unpleasant acrid smell, and their value is in consequence very much lower. This is due to the abstraction of the non-volatile constituents, together with a certain amount of decomposition arising from the high temperature.

The comparative paucity of information concerning the characteristics, chemical and physical, of hand-expressed lime oil (or otto of limes), as well as of the distilled oil of limes, prompted the collection of a number of samples from Dominica and Montserrat for purposes of examination in the Government Laboratory, Antigua.

For the purpose of this investigation, seven samples of expressed oil and three samples of distilled oil were obtained; these are identified by letters as follows:

A. .....Hand-expressed oil, Antigua
B. .....Hand-expressed oil, Antigua
C. .....Hand-expressed oil, Montserrat
D. .....Hand-expressed oil, Montserrat
E. .....Hand-expressed oil, Montserrat
F. .....Hand-expressed oil, Dominica
G. .....Hand-expressed oil, Dominica
H. .....Distilled oil, Dominica
I. .....Distilled oil, Dominica
J. .....Distilled oil, Dominica

With the exception of samples A and B, which were produced on the same estate but at different times, the remaining samples of expressed oil and distilled oil were produced on estates at different points in Montserrat and Dominica. In every case there is no doubt as to the authenticity of the samples, which are all of recent origin.

On each of the foregoing samples was determined (1) the specific gravity at 30°C.; (2) the optical rotation in a 100-mm. tube (at 31°C.); (3) the refractive index (at 32°C.); (4) the citral content by Burgess and Child's method; (5) the acid value, by titration of 5 c.c. of the oil dissolved in alcohol, with N/2 alcoholic potassium hydroxide in the cold.

The results are given in tabular form (Table LVII).

(*La Parfumerie Moderne. Photograph by M. Gillet*)

WEIGHING CITRONS IN CORSCIA.

(*La Parfumerie Moderne. Photograph by M. Gillet*)

A SHIPMENT OF CITRONS AT BASTIA, CORSCIA.

HAND-EXPRESSED OIL

Properties and composition.—This oil is of a golden-yellow color, and is hardly distinguishable from a good lemon oil by its odor. The most important constituent is citral. It contains also a paraffin, limonene, and methyl anthranilate and 10 to 18 per cent of non-volatile residue. The oil gives a cloudy solution in four to ten volumes of 90 per cent alcohol with separation of wax or paraffin-like constituents.

With regard to the hand-expressed oils, an examination of the results shows a somewhat wider divergence between the character of the different oils than that indicated by figures given by the various authorities already quoted, although they are in general agreement with them. The figures for the optical rotation are somewhat lower than one would expect; this is probably partly accounted for by the expansion of the oil owing to the high temperature at which its measurements were made;

TABLE LVII

Sample	Specific Gravity at 30°C.	Rotation in Angular Degrees at 31°C.	Refractivity at 32° C.	Citral Per Cent	Acid No.
Expressed Oils:*					
A	.....	31.38	1.4851	6.6	2.8
B	.8859	31.63	1.4836	5.2	2.7
C	.8752	32.11	1.4816	5.2	2.6
D	.8712	32.80	1.4809	2.4	1.6
E	.8740	32.67	1.4815	4.0	2.04
F	.8664	33.43	1.4789	2.4	1.35
G	.8659	32.94	1.4789	2.2	1.44
Distilled Oils:†					
H	.8540	34.30	1.4713	2.0	1.3
I	.8858	34.89	1.4702	1.4	0.76
J	.8567	33.09	1.4712	1.2	1.1

* Density at 15° C. 0.878 to 0.901, mostly between 0.880 and 0.884
Rotation + 32° 50′ to + 37° 30′ (Schimmel, October, 1909)
+ 35° to + 38° (Gildemeister and Hoffman)
+ 36° to 40° (Allen)
Rotation of the first 10 per cent of the distillate rather higher, or at most 4 per cent lower, than that of the original oil.
Refractive index at 20° C. 1.482 to 1.486
Acid number up to 3.0
Ester number 18. to 3.0

† Density 0.865 to 0.868 (Gildemeister and Hoffman, temp. not given).
Rotation + 38° 52′ (Gildemeister and Hoffman, temp. not given).
+ 46° 36′ (Schimmel, October, 1904)

possibly also the specific rotation of the optically active constituents may tend to decrease with rise of temperature.

Citral and acid content.—The citral content and the acid number vary markedly in the different samples: it is interesting to note that a fairly close correlation appears to exist between the two figures; subsequent investigation, however, appears to lend some color to the view that the relatively high acidity recorded in the case of these oils with a relatively

high citral content may possibly have been due in part to interaction between the aldehyde and alcoholic potassium hydroxide used for the titration.

The citral determination by Burgess' methods seems to give satisfactory results, and the appearance of a marked line of demarcation between the oil and underlying sodium sulphate solution would appear to indicate the absence of citronellal.

The citral content as determined in this way varies markedly in different samples. On the whole, the citral content of the hand-expressed oil is lower than is the case with lemon oils, which according to Gildemeister and Hoffman contain 7 to 10 per cent of that constituent.

DISTILLED OIL

Properties and composition.—Distilled oil has an unpleasant odor, like turpentine or pine tar oil, and no longer reminds one of citral. Probably this aldehyde is completely destroyed by the boiling of the acid liquid. The oil boils between 175° and 220°. The residue on evaporation is 3 per cent.

TABLE LVIII

Fraction	Temperature (C.)	Approximate Volume (c.c.)	Refractive Index at 28° C.
1	155°		1.4705
2	155°–169°	20	1.4708
3	169°–171°		1.4711
4	171°–173°		1.4708
5	173°–175°	50	1.4709
6	175°–177°		1.4711
7	177°–179°		1.4713
8	179°–182°		1.4719
9	182°–186°		1.4721
10	186°–190°	20	1.4737
11	190°–195°		1.4742
12*	195°–200°		1.4736
13†	200°–235°		1.4890
14	Tarry residue	10	

(Refractive index of original oil = 1.4770 at 32° C.)

*Bluish liquid.
†Blue liquid filtered from crystals (see p. 301).

With regard to the distilled oils, samples I and J came from the same estates as samples F and G; no corresponding sample of expressed oil was obtained from the estate supplying the sample H. The samples appeared to be characterized, on the whole, by a lower refractive index, citral content, acid number, and in the case of H and I, a lower specific gravity. The rotation, on the other hand, is in all cases somewhat higher.

To obtain a certain amount of further information regarding the different bodies of which the oil is made up, a sample of hand-expressed oil was subjected to fractional distillation.

The original samples were taken from sample G, and 100 c.c. taken for the distillation. The temperature, and corresponding approximate volume of oil distilled and refractive indices of each of the fractions, are given in Table LVIII.

As is seen from Table LVIII the greater portion of the oil distilled over between 171° and 177°C. It appears that this fraction consists largely of limonine or closely related bodies. At 200°C. decomposition set in and the distillate became slightly blue, the contents of the flask turning dark green. As the temperature rose a deep-blue oil distilled over, and the green color of the liquid in the flask became more intense. At 235°C. the vapor was also colored and the distillation was discontinued. About 10 c.c. of a tarry-brown liquid remained, which on cooling solidified to a hard, vitreous, black mass.

TABLE LIX

Fraction	Temperature (C.)	Approximate Volume (c.c.)
1	175°	15
2	175° – 178°	60
3	178° – 182°	
4	182° – 186°	
5	186° – 205°	20
6	205° – 245°	
7	Residue	5

The blue fraction on standing deposited pale-yellow crystals leaving a deep green mother-liquor. These were separated, dried, and crystallized several times from chloroform. A very light, faintly yellow substance was obtained, crystallizing in fine needles and having the melting-point at 131.5°C. Its nitrogen content was determined and found to be 11.16 per cent.

One hundred c.c. of distilled oil from the same estate was next subjected to fractional distillation in the same way (Table LIX).

TABLE LX

Fraction	Temperature (C.)	Approximate Volume (Per Cent)
1	170°	19
2	170° – 172°	30
3	172° – 175°	25
4	175° – 180°	15
5	180° – 235°	9
6	Residue	2

As 200° C. was reached, signs of decomposition were evident: the distillate became green and this color was intensified as the temperature rose. A few c.c. of a deep-green liquid were left in the flask. No change was observed in this on standing, and no crystals were deposited.

For purposes of comparison, a steam distillation was performed on about 75 c.c. of expressed oil. This gave a perfectly clear oil with the characteristic terebinthinate distilled oil odor. The portion remaining undistilled consisted of a heavy, opaque, greenish oil, which retained in a modified form the odor

of the original oil. The distillate was subsequently fractionated and the fractions of Table LX were collected.

Decomposition set in about 185°C., and a small quantity of a golden-yellow oil remained undistilled in the flask.

Methyl anthranilate.—From the foregoing results, it would appear that during the process of distillation with steam (the conditions under which ordinary distilled oil is obtained being practically those of a steam distillation) a certain proportion of the lower and higher boiling constituents are removed. The blue fluorescence due to the presence of a crystalline substance in the higher fractions of the expressed oil is entirely absent in those of the distilled oils. This substance possibly may be the methyl anthranilate which is known to exist in lime oil (Allen), to the methyl ester of which—$C_6H_4(NH \cdot CH_3) \cdot COOCH_3$—E. J. Parry ascribes the blue fluorescence of mandarin orange oil.[1] This is probably removed during the steam distillation.

Limettin.—Expressed oil on standing generally deposits a pale-yellow crystalline substance known as limettin. Distilled oils do not deposit this body. Limettin is stated to be dimethoxy-cumarin; it is readily soluble in hot water, and it is possible that distillation with steam effects the removal of the limettin itself, or of that constituent of expressed oils which by the action of light may be converted into limettin. (A sample of limettin recrystallized from boiling water was found to have a melting-point of 115°C.)

Citral.—The proportion of citral is also less in distilled oils than in the corresponding expressed oil, owing, probably, to some chemical change brought about during the distillation.

These, then, are some of the possible causes of the marked difference between expressed and distilled oils. At present, however, our knowledge of the constituents of the oils is far too meager for us to be able to explain fully the nature of the changes taking place during the steam distillation of an expressed oil.

FRENCH WEST INDIES

Small quantities of citrate of lime are exported from Martinique.

PORTO RICO

The commercial development of citrus-growing in Porto Rico dates from the time of the American occupation in 1898. Before that oranges, limes, and lemons were grown for home consumption but practically none of these fruits were exported. Consequently the amount of citrus

[1] Allen's *Organic Analysis,* 1907, Vol. II, Part III, p. 40.

(Powell and Chace, U. S. Dept. of Agric. Bull. No. 160)

TERRACES OF LEMON TREES ON THE MOUNTAIN SIDE NEAR MAJORI, ON THE AMALFI COAST.
Masonry walls are built to keep the land from sliding,

(Powell and Chace, U. S. Dept. of Agric. Bull. No. 160)

TERRACES OF LEMON TREES RISING FROM THE SEA IN SICILY.
The larger trees are olives. There is a trellis over each terrace for protection from frost.

fruit products was not of commercial importance previous to 1898. Canned grapefruit is now the principal product exported. The amount of this commodity shipped varies from year to year in accordance with the supply and demand not only for the product itself but for fresh citrus fruit as well.

The intimate relation, therefore, between citrus fruit and citrus fruit products makes it imperative to describe the citrus fruit industry.

People from the United States came to Porto Rico for the purpose of growing fruit. Orange and grapefruit trees were planted extensively in the Rio Piedro–Bayamón section as well as in the Espinosa plantation section, and scattering from there along the coastal plain to Arecibo. Some of the early planters had acquired a knowledge of citrus fruit-growing in Florida, but the great majority started in without practical knowledge of tropical agriculture or horticulture. Consequently some failures resulted but the industry became stabilized in a short time.

Many trees were stunted by scale insects, principally *Mytilaspis citricola*. However, scale was found to thrive only when trees grew in dry air or windy localities. Under humid conditions the scale does not thrive because it is here subject to fungi attack. The planting of wind-breaks resulted in a more humid condition, fungi growth, and scale death.

Grapefruit were found to grow better than oranges no matter on what stock they were budded. Orange trees are nevertheless planted for shade in coffee plantations. Neither lemons nor limes are produced in commercial quantities. Limes should do well in Porto Rico, as they grow well in the West Indies where similar climatic and soil conditions exist.

The citrus industry in Porto Rico is hampered by drought in the winter months and at infrequent periods by hurricanes as in 1898. Difficulty in transportation not only within the island itself but also from the island to market was formerly an important factor. In 1898 wagon roads were not built far enough into the interior to allow wheeled vehicles to enter, and of course carrying fruit on horseback down mountain trails was not satisfactory. Ships were not fitted for carrying fruit and therefore a great deal of fruit decayed before reaching market. Sales reports frequently showed 15–25 per cent decay on arrival in New York. It was not until 1920 that properly ventilated ships became available. At that time a steamship line began transporting fruit from Porto Rico to New York under refrigeration or forced draft. Since then other lines have equipped their ships with proper ventilation and some with refrigeration.

The chief loss from decay in Porto Rico fruit shipments was due to stem-end rot caused by a fungus (*Diplodia natalensis*). The destructive

action of this fungus is prevented by sealing the cut stems of the fruits with shellac immediately after the fruit is clipped from the tree.

Acreage.—According to the United States census report of 1920 there were then 219,000 bearing grapefruit trees and 114,000 non-bearing trees.

Orange trees approximate 100,000 upon an area of 1,300 acres. The total area planted in citrus trees is 6,000 acres. The acreage would have been greater if better transportation had been afforded as there is plenty of suitable land still available. Any soil that will produce coffee will produce citrus fruit. Consequently the 40,000 acres now planted to coffee could be used for fruit raising.

As Table LXI shows the amount of fruit shipped from Porto Rico in the past has varied considerably from year to year. This variation is not due entirely to differences in yield as often the selling price determines the amount of fruit shipped. Recently a number of canneries have started canning grapefruit.[1] They pay the grower as high as $25.00 per ton for the fruit. Orange canning is not practiced.

TABLE LXI

ANNUAL SHIPMENTS OF CITRUS FRUIT FROM PORTO RICO SINCE 1910 (ACCORDING TO CUSTOMS REPORT)

Year Ending June 30	GRAPEFRUIT		ORANGES	
	No. of Boxes	Value Declared	No. of Boxes	Value Declared
1910.....	48,441	$ 162,749	296,058	$ 582,716
1911.....	96,189	309,698	349,442	703,969
1912.....	118,937	525,048	277,422	584,414
1913.....	216,247	726,811	353,690	740,091
1914.....	206,200	751,769	348,927	752,180
1915.....	276,583	834,440	200,311	378,181
1916.....	296,645	837,014	404,451	790,797
1917.....	435,890	939,677	503,318	1,009,737
1918.....	549,125	1,120,330	603,226	1,231,551
1919.....	417,369	739,106	373,679	770,303
1920.....	419,629	1,332,742	336,625	833,575
1921.....	667,637	2,019,557	162,817	447,426
1922.....	360,530	1,100,727	388,182	923,912
1925*.....	580,000	1,756,000	337,000	838,000
1926*.....	809,000	2,480,000	464,000	1,196,000

**Foreign Crops and Markets*, Vol. XIII, No. 13, 1926.

An orange marmalade is made from the bitter oranges of Porto Rico by some of the native women and sold locally. It is said to equal the best of the Dundee product. A marmalade is also made from grapefruit.

[1]In 1925, 3,841,000 lb., and in 1926 6,348,000 lb. (estimate) of canned grapefruit was exported to the United States. (*Foreign Crops and Markets*, Vol. XIII, No. 13, 1926.)

HAITI

The average orange of Haiti is not as good as that found in the neighboring islands. Lack of care, as these fruits are left to grow practically wild, has resulted in the product being poor compared to that of Cuba, Porto Rico, and Jamaica. Some of the oranges on the southern coast possess much of the same aromatic properties of their peel as those of Curaçao; the peel of the oranges from the latter island is the base of the cordial of the same name. Therefore a demand has arisen for the Haiti south coast orange peel. The Netherlands is the principal purchaser of the peel. There is no section of Haiti where oranges do not grow, and with care and attention superior fruit could easily be produced.

DUTCH WEST INDIES (CURAÇAO)[1]

The "Curaçao liqueur" which has done much to make the island known, is not made in Curaçao at all. It is made in the Netherlands, having acquired its name because orange peel from the island of Curaçao is one of the principal ingredients. Owing presumably to the dryness of the island, the orange peel produced there possesses a peculiar flavor and strength, which no other peel seems to have. Orange peel is one of the staple articles of export, though the native supply is not large. A few unimportant attempts have been made to manufacture "Curaçao" locally, but they have not proven successful. The total exports from the island during the most recent year for which figures are available were less than 150 gallons. Doubtless .50 per cent of this was brought over from Holland and exported by the Willemstad houses.

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[1]See p. 319.

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CHAPTER XIV

THE INDUSTRY IN SOUTH AMERICA[1]

ARGENTINA

The total number of orange trees in 1908 was 2,117,000 while the lemon trees numbered 64,000. Corventes is the leading province in orange culture reporting an area of 15,987 acres carrying 1,514,000 trees. The local production of both oranges and lemons is insufficient to meet the demand. The amount of citrus by-products made is not known.

BRAZIL

The annual average for the oranges exported for the three years, 1910–12, was $11,788 and tangerines $3,805.

CHILE

Oranges and lemons are raised in small areas in Chile.

PARAGUAY

Orange growing is the principal fruit industry of Paraguay. The number of orange trees of bearing age was estimated as 1,500,000 in 1913.[2] As many as 164,271,000 oranges and 3,768,000 mandarins were exported in that year. The following excerpts from a book on Paraguay by E. de Bourgade la Dardye give an idea of the potentiality of the country as a producer of citrus products.

Everywhere, on the banks of the rios, in the gorges of the far-off sierras, near the ranchos, round the estancias, in the solitude of the forests, the trees are seen with their golden fruit and deep green foliage, in lines, in terraces, in groves—everywhere, on mountains and on plains, they grow and break the blue horizon with their rounded outline; and it seems as if they must have flourished there from all antiquity.

I am quite ready to admit that the sweet orange, the bitter orange, the lemon, and their numerous varieties were imported either by the Spaniards or by the Jesuits; of this there can be little question; the original habitat of them all was in Asia, and the history of their dissemination is well known;

[1]In 1586, Cavendish found on the island of Puna in the Gulf of Guyaquil, in what is now Ecuador, an orchard of "orenges, sweete and sower, limons, pomegranates, and lymes." These may have been introduced from the Philippines as the Spaniards introduced coconuts from this source. (*The Third Circumnavigation of the Globe . . . . of Thomas Candish.*)

[2]A new Italian colony near Villeta finished planting in July, 1926, 127,000 orange trees. (*Foreign Crops and Markets,* Vol. XIII, No. 4)

but at the same time there is a Paraguayan orange especially belonging to itself. It has a flavor that is slightly acid, which makes it very acceptable in hot weather; without cloying the palate like the sweet orange or setting the teeth on edge like a lemon. It seems to cleanse the mouth in a way that is very refreshing. So far from growing everywhere, it is found chiefly in the depths of the forests and on the banks of insignificant streams. I have met with it in the most remote places, in the unexplored valleys of the Ygatimi, and on the margin of the Upper Parani, where it could certainly never have been introduced by human agency. So abundantly does it grow on the Parana above the Salts de Guayra that during a flood I have seen numbers of the trees drifting down the stream.

.....

But after all, whether oranges of any kind are indigenous to Paraguay or not, it is very certain that they well might be for the whole world could not show a soil that is more favorable for their growth. Without attempting to enumerate all the varieties of oranges and lemons that are found, I may mention the following as being the most common. The sweet orange (*Citrus sinensis* L.), the bitter orange or bigarrade (*C. Aurantium* L.), the mandarin orange, the apepu, the citron (*C. medica*), the toronjo (*C. limonium citratus*), the common lemon (*C. Limonia*), the lime or sweet lemon (*C. aurantifolia*), and the lime of Persia.

It would be quite impossible to form a true estimate as to what extent of area in Paraguay is taken up by this orange growth. Sometimes singly, sometimes in clumps, sometimes in vast forests—as in part of the Missions—the trees thrive in almost every district, here under cultivation, there entirely wild.

According to the reports from Paraguay the most ruinous methods are being employed which have resulted in complete annihilation of the underbrush of orange trees or Manchones over wide areas (Mazuyer). In his book, *Paraguay in Wort und Bild,* R. von Fischer-Treuenfeld renders the following account:[1]

Although wild orange groves are still numerous, they are, because of the pernicious methods practiced, remote from the inhabited places. The harvest is carried on all year, but principally from October to April. About 5 cm. above the ground the trees are chopped down. The leaves and young fruits are distilled on the spot, the wood being used as fuel. Thus indolence and vandalism have led to the annihilation of the orange forests. More recently the Government has endeavored to prevent the chopping down of the trees and to regulate the harvesting by law. Hence the price of the oil has risen and it is more and more difficult to obtain the product.

OIL OF PETITGRAIN[2]

The term petitgrain, under which the essence is commonly known in industry and commerce, is derived from the primitive processes of extrac-

[1] *Report of Schimmel & Co.* (April, 1902), p. 55.
[2] See also pp. 195-98.

tion from scarcely formed green fruit when no larger than a chestnut or beechnut. The product now extracted from the leaves is similar to that obtained from the small fruit, and through force of habit the old name has been preserved.

The bitter orange tree, the "naranjo agrio" of the country, whose leaves form the source of the oil, is found growing wild over the same wide area in which the sweet orange flourishes so spontaneously, though it is of more frequent occurrence in the forest region than is the latter variety. It is distinguishable by the form of leaves and the greater coarseness of the rind of the fruit, which is also generally larger than the sweet orange. It is also distinguishable from the "apepu" or native bitter orange.

The petitgrain industry is centered in a zone about the small town of Yaguaron, although the trees are increasingly exploited outside this area, especially in the region east of the railway. Distilling is carried on in the neighborhood of the villages of Ita, San Jose de la Cordillera, Itacuruby, and Nemby, all of which lie within about 60 miles of Asuncion. The number of distilleries producing petitgrain oil in 1909 was estimated at thirty[1] located as follows: twenty in Yaguaron,[2] four in Ita, three in San José de la Cordillera, one in Itacuruby, and two in Nemby. Collectively they had a capacity of from 2600 to 3000 kg. monthly or about 36000 kg. annually.

The Jesuits are credited with having been the first to exploit petitgrain, but the exact date of the inception of this industry is unknown. In 1873 the industry was modified through the efforts of a French botanist, Balanza, who visited Paraguay to study the flora of the country and who then examined the properties of the oranges. He became interested in the production of "Agua de Azahar," or the extract of orange blossoms, but finally turned to the utilization of the leaves of the bitter orange tree. He proved the practicability of substituting the leaves for the blossoms as the base of perfumes hitherto derived from the latter source, and thus laid the basis of the present industry. The rather crude method of extraction which he devised has been changed but little since his time, though a process, kept secret by its users, of refining the raw product has since been invented.

The only equipment of those engaged in the industry is a simple still,[3] which can be carried from place to place if necessary. The still is set

[1] *Le Messager de Sao Paolo* (September 7, 1909); also *Report of Schimmel & Co.* (April, 1910), p. 89.

[2] *Chemist and Druggist*, LI (1897), 110.

[3] See Plate XII.

up in a palm-thatched hut, to which the gatherers bring the leaves for distillation. These are packed into a receptacle like a barrel, the bottom of which has been perforated with holes for the admission of steam. A steam-generating apparatus, the wood fuel for which is picked up in a nearby forest, forms steam at a pressure not in excess of one atmosphere. The vapor which results from the saturation of the steam with the volatile oil of the leaves is carried off through a pipe at the top of the vat to the coils of another chamber, where it is condensed by cooling.

The condensed liquid passes into a florentine flask which acts as a receiver and separates the water from the oily essence. The essence may be now said to be ready for market although some producers think it necessary to purify by filtration. The process of further distillation for refining the product thus obtained is carried on by houses in Asuncion, which export the essence to the foreign buyers.

TABLE LXII

Countries	1915	1916	1917	1918
	(kilos)	(kilos)	(kilos)	(kilos)
France	17,111	26,064	29,918	10,948
Netherlands	7,335	3,132	.....	.....
United States	5,119	3,156	8,318	6,052
Argentina	4,921	7,910	11,413	4,599
Uruguay	1,425	113	262	341
Italy	1,080	1,160	2,660	1,350
Denmark	884	.....	.....	.....
England	308	679	1,154	253
Germany	240	.....	.....	.....
Spain	.....	4,021	7,421	12,380
Brazil	.....	.....	266	240
Chile	.....	.....	86	.....
Total	46,423	46,235	61,498	36,163

The natives gather the leaves and receive about 12 cents per 20 lb. It is customary to cut down the trees for stripping, but where this is not done a tree can be stripped once every two years. Between 500 and 600 lb. of leaves are necessary to produce a quart of the unrefined oil, and the usual still will produce about 4 qt. a day. The labor attached to the distillation process is inconsiderable. As soon as the apparatus has been charged for a thirty-six-hour run it is only necessary to see to the keeping up of the fire which takes one person about three hours a day. A small distillery of the Balanza system produces on an average 50 qt. (or kilograms) of essence of petitgrain a month, and on gross receipts of $144 a net gain of $120 is made. The oil is placed for exportation in tin boxes

(*Powell and Chace, U. S. Dept. of Agric. Bull. No. 160*)

ONE OF THE BETTER TYPES OF GROVES AT MASCALI, SICILY.

Showing the high-headed trees, a distributing furrow between the rows, and basins around the trees.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

A GROVE OF LOW-HEADED TREES IN CALIFORNIA.

holding 2 kg. These tin boxes are made especially for this purpose and have a small opening at the top, which is sealed as soon as they are filled.

The essence is in good demand as a basis for perfumes and flavoring extracts, and about 70 per cent of this demand is supplied by exports from Paraguay. For a long time France took most of the production, but during 1916 a good market was opened with Spain.

Exports by countries for the years 1915 to 1918 are given in Table LXII.

The exports credited to Argentina and Uruguay are, of course, largely shipments in transit, the ultimate destination of these consignments being Europe or the United States.

TABLE LXIII

EXPORTS OF PETITGRAIN FROM PARAGUAY FOR THE YEARS 1914 TO 1920

Years	Quantity in Pounds
1912	52,704
1913	71,322
1914	26,159
1915	38,425
1916	46,235
1917	61,498
1918	36,163
1919	37,976
1920	73,675

A full description of the chemical and physical properties of the oil is to be found in chapter x (pp. 195–98).

BRITISH GUIANA

Limes are cultivated over about 1,350 acres, and the erection of factories for the production of concentrated juice and citrate of lime has given the industry a much desired impetus; the exports were (1919) 389.5 cwt. citrate of lime, 7,356 gal. of raw and 2,882 gal. concentrated lime juice and 326 gal. of oil of limes.

URUGUAY

One-fourth of the total area in fruit trees in 1908 was devoted to oranges (16,884 acres) comprising 501,119 trees with a fruit production of 6,292,759 pounds.

1,403 acres of lemons growing 40,332 trees produced 315,901 pounds of fruit in 1908. At this time the local orange production was insufficient to meet the demands of the country. No record has been obtained of the amount of by-products produced.

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CHAPTER XV

THE INDUSTRY IN EUROPE

GREECE

The citrus region is confined to the provinces of Vostizza, Agrinion, Diakopton, and Akratas. The first two produce most of the finer fruit exported to the United States. Heavy frosts in early November[1] wrought losses amounting to 40 per cent of the crop. Curiously enough the lemon and orange crops of Western Greece escaped all frost damage but suffered a general loss of 45 per cent from fly damage.[1]

The 1920–21 citrus crop in the consular district of Patras, Greece, is reported to have shown an increase of 20 per cent in production and an increase of approximately 30 per cent in prices. The American Consul at Patras said that this price increase ranged from 25 per cent on low-grade fruit to 40 per cent on the best grade. American buyers in 1919

TABLE LXIV*

GREEK PRODUCTION OF CITRUS FRUITS, 1921-22 TO 1923-24

Fruit	1921-22 (Numbers)	1922-23 (Numbers)	1923-24 (Numbers)
Oranges	53,000,000	152,000,000	61,100,000
Mandarines	18,000,000	63,000,000	58,100,000
Lemons	31,000,000	49,000,000	29,000,000

*_Chamber of Commerce Journal_, London, May 2, 1924, p. 247. _Consular Report_, Athens, January 4, 1923.

imported 1,007,686 lb. of citrons in brine from Patras and local citrus exporters considered that the demands in hand assured a considerable increase in American business. The principal reason given for higher prices was the heavy cost for cutting, brining and barreling. This cost increased from $0.61 per 100 lb. to $1.29, because of higher wages and greater costs of cooperage.

SPAIN

The chief centers in Spain are the provinces of Valencia, Castellon, and Murcia on the east coast, and the provinces of Seville and Cordoba.

[1]_The Market Reporter_ (United States Department of Agriculture), III, No. 10 (March 5, 1921), 159.

Valencia is pre-eminently the sweet orange region. Lemons, on the other hand, are not produced to any extent in the Valencia district. Lemons are grown extensively, as is the bitter orange used for marmalade, in the Province of Seville. It is estimated that the total acreage in Spain planted to oranges in 1922 is 225,000 acres. Lemon trees, although in flower the year round, bear their greatest crops in November, April, and May. Orange lands are valuable and sell from $700 to $1,000 per acre; the average yield per acre is 20,000 lb.; the average yield per tree, about 275 lb.

Spain is a source of a small amount of citrus products.[1]

FORMER AUSTRIAN EMPIRE

From 1909 to 1913 inclusive exports of lemons and citrons were valued at $435,000 per annum and oranges $209,000 per annum. In the fiscal year ended June 30, 1914, Austria-Hungary exported to the United States 652 lb. of citric acid.[2]

FRANCE

The exports of citrus by-products to the United States for the year ending June 30, 1914, were artificial oil of bergamot 121 lb., hand-pressed oil of bergamot 212 lb., oil of lemon 1,543 lb., oil of neroli 7,839 lb., oil of orange 3,040 lb., oil of petitgrain 5 lb., terpeneless oil of petitgrain 4 lb., orange peel 15,684 lb., and essence of orange flowers 25 lb. Later statistics are included in the Appendix.[3]

Corsica is the largest producer of citron.[4]

ITALY

GEOGRAPHICAL DISTRIBUTION OF THE BY-PRODUCT INDUSTRY

In northern Italy the manufacture of citrus products is unprofitable; the industry flourishes only in the southern part of the country. In Sicily, especially along the southeastern coast, it constitutes one of the chief sources of income to the people. The world's supply of bergamot oil comes principally from the province of Calabria. Much higher prices are obtained for it than for lemon oil. In Sicily is found the largest lemon-growing region in the world; it lies along the northern and eastern coast and is naturally divided into five parts. Listed in order of their importance they are: the Etna district, the Messina district, the Palermo district, the Syracuse district, and the north coast district.

[1]For additional statistics, see pp. 348, 355.
[2]For additional statistics, see pp. 355, 365.
[3]See pp. 348, 354, 355, 364, 368.
[4]See Plates XIII, XIV, and pp. 110–12.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

PICKING AND GRADING THE FRUIT, PALERMO, SICILY.

The lemons are being graded roughly for by-products and for export.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

INTERIOR OF A PACKING-HOUSE AT CATANIA, SICILY.

Showing the padded bins used in grading and packing.

The industry near Etna.—This district lies on the eastern coast of Sicily and extends from Catania on the south to Giardini on the north and takes in the towns of Francavilla, Bronte, Aderno, and Paterno which lie on the watershed of Mount Etna.

Aside from fresh fruit the principal products of this district are lemon oil, orange oil, and citrate of lime. These are sent by rail to Messina for export.

Catania, the southernmost city of this section, contains one lemon-oil factory of considerable size with many smaller ones in the suburbs. In the smaller manufactories the fruit is prepared in the street, and the oil extracted in the living-rooms and stored in the sleeping-rooms of the houses. According to Chace the only place given over exclusively to the manufacturing process is the room devoted to calcium citrate and this may serve also as a stable. A small number of culls are bought from time to time as needed, and the whole family takes part in transforming them into the final products.

Acireale, a small thriving city, is the most important center of this industry in the Etna district. With a dozen or more factories, it is also headquarters for the Essential Oil Producers' Association, an organization of comparatively recent formation, the membership of which seems to be confined to producers in the Etna district.

North of Acireale, 6 miles distant, is Giarre, with one factory of fair size and several of minor importance. About 2 miles nearer the foothills of Mount Etna, at the railroad station for Mascali, is a small village called Carrubba, whose inhabitants, men, women, and children, are employed in a group of large factories situated there. One of these factories is the largest and best equipped in Sicily, employing at the height of the season over three hundred hands, producing several hundred pounds of oil a day. Even here such advance as has been made does not seem to have changed the character of the methods employed, the improvements often being more apparent than real, and emphasized by the crude conditions surrounding them.

Mechanical carriers are used for conveying the fruit from one part of the factory to the other and for carrying off the waste products, but no devices for halving the lemons or removing the pulp from them have been attempted. A battery of machines for extracting the oil from the peel was at one time installed, but later abandoned. It is not strange that the device was a failure, for the peel required the same preparation as in the present methods of handling, and each machine needed an attendant, who handled separately every half lemon rind. As the rate of production was not greatly increased, the apparent saving was the difference in cost between the hire of a boy or girl attendant and that of a man sponger minus the cost of power necessary to operate machines. After all, however, the place is exceedingly well equipped when compared with other Sicilian factories, having cement floors and tanks, an electric lighting plant, steam ovens for drying citrate of lime, and many other improvements not usually seen on the island.

The two neighboring factories are of the usual type, but well arranged and roomy, employing about fifty hands each. They produce in the neighborhood of 100 lb. of oil daily.

Several miles northwest of this point, on the first of the foothills of Mount Etna, is the town of Mascali, containing several small factories of

minor importance, drawing their fruit from the upland valleys of the vicinity. The other two centers in the district are Fiumefreddo and Giardini. The former contains several factories of a daily capacity of 50 to 100 lb. of oil; the latter, one large factory and several very small ones, there being in addition several small places between the two towns. Giardini is the northern limit of the district and draws its supplies from the south, being cut off from the Messina district on the north by a steep range of hills, over which hauling is difficult even on the fine military road which skirts the coast. Fiumefreddo is 6 or 7 miles farther south and is surrounded for miles on all sides by lemon gardens. The whole region from Catania to Giardini lies at the foot of Mount Etna, many of the fruit orchards being on its decomposed lava beds.

Oranges are also grown in this district, but are as a rule farther inland in the foothills. Aderno, Paterno, and Bronte, situated well up on the slopes of Etna, have considerable of this trade, as has Francavilla, farther north, nearer Giardini, the large factory at the latter place producing considerable quantities of both sweet and bitter orange oil from the fruit grown here.

The season begins in the Etna district in December and is practically over by April 1, although a few small operators continue into May. As the growing of Verdelli lemons is less practiced in this region than in the Messina district or in parts of the north coast, the inducements for summer work are not the same. The output of the district is marketed at Messina, being shipped to that point by rail, the exportation of oil and citrate of lime from Catania being less than the production of that city alone.

The industry in the Messina district.—The Messina district, the second largest in Sicily, is practically a continuation of the Etna district on the south. The lemon-producing land lies along the coast, extending into the few valleys which run back between the hills as in that district. The soil, however, is probably quite different, as it is much farther from Mount Etna, no lava streams having entered the section for many hundred years.

The largest center at the southern end of the district is Santa Teresa, from which the oil of the neighboring town Roccalumera is also shipped. There are eight or more factories in the two places, one of which is considerably above the average size, employing a hundred hands or over, the others varying from those employing less than a dozen to those which have upward of fifty. Northward toward Messina, the next center of importance is Scaletta Zangles, where are located three or four factories of very small size. At the northern end of the district, from Galati to Messina, the coast belt is much narrower than toward the south; the towns here stretch continuously along the military road, there being scarcely a visible boundary between them. When riding along this road the whole region seems an extension of the city of Messina.

The chief centers are Galati, Tremestieri, Mili, and Contesse, all small towns having direct railroad connections with the city. The factories are, taken as a whole, better equipped than elsewhere in the island. Mostly they are of moderate size, some employing less than twenty hands, though one, with over two hundred, is second or third in size in Sicily. This factory is one of the very few to produce concentrated oil by fractional distillation of the usual product. Owing to the size of the factories and the narrowness of

the coast strip here, a large quantity of the fruit consumed is drawn from farther south, and during the bergamot season from Calabria, on the mainland.

Messina itself is hemmed in on all sides by high hills upon which no lemons are grown; fruit in large quantities must, therefore, come from some little distance. For this reason there is but one factory of any considerable size in the city; it employs, however, over two hundred hands, being situated on the north side of the city in an isolated group of groves.

Messina, like Catania, contains many very small places where oil is made in the dwellings of the lower classes, the output in any single instance being small, but the total of some importance. There was also at one time a quantity of products made here from the culls of stored fruit which has given way before the Verdelli lemon.

On the north coast, not far from Messina, are two centers of minor importance, Bauso and Rometta. There seems little reason for classing them with the remainder of the Messina district except for the fact that they employ methods of production similar to those used on the south coast, while the center nearest them on the north coast employs a somewhat different process in obtaining oil. Undoubtedly, however, as far as the oil is concerned its composition here is more nearly like that of the north coast, no matter what process is used in its production. The factories in those towns are quite small, especially at Rometta, Bauso containing one of the average size, employing nearly fifty hands.

As in the Etna district, the produce of the entire Messina region is disposed of through Messina brokers. The season also is the same as in that district.

The industry in the Palermo district.—Palermo, the third district of importance, is the most westerly of the five. As in the other north-coast regions, lemon cultivation occurs in large isolated groups of orchards, with the exception of the Conco d'Oro, where the whole valley is given up to it. This valley is of exceptional fertility, and it is said that at one time considerable sugar cane was raised here. The fruit being above the average quality, the greater part of it is shipped fresh. The culls for by-products go both to Palermo and to the small city of Monreale, beautifully situated above Palermo in the hills. Here are some half-dozen poorly equipped factories of small size, employing from a dozen to thirty hands each.

Palermo itself is the largest city of Sicily and contains several important factories, situated largely in the suburbs; the output of oil is not, however, larger than that of some of the small towns of the south coast. Information about the factories here is much harder to obtain than in other parts of Sicily; there are at least six of average size, the city being free from factories of the smaller type such as are found in Catania and Messina.

Toward the east, the principal center is Ficarazzi, where there are several factories, one of which may be said to be large. There are also other towns to the west of Palermo which contain manufacturing plants, but they are small and relatively unimportant. At Pattinico, on the Trapani railroad line, are two or three, at Carini one, and at Cinisi another; taking it all in all, they are the crudest of the island.

While this district produces a large quantity of oil and citrate of lime, the industry is not so well developed as in the two districts already described, these commodities here being in every sense of the word by-products.

The production of summer lemons is universal in this region and affects to a considerable extent the composition of the essential oil. This is probably due to admixture of oil produced from the Verdelli lemons left upon the trees until the following season. Ordinarily the amount thus produced is small; when, however, the price of summer fruit is low it is very often left unpicked until the following natural crop is gathered, when it is sorted out with the other culls. In some factories this fruit is discarded, no attempt being made to produce oil from it. In the majority of cases, however, it is worked up as usual. It would seem that the former is far the better policy, as the yield both of oil and of citrate of lime are extremely low, added to which is the further disadvantage of the inferiority of the resulting oil. Where this fruit forms a considerable proportion, the resulting product is not marketable except in admixtures with normal oil.

The season begins here later than in any of the other districts, often two months later than at Syracuse, and extends later into the warm weather, the month of June often finding several factories still in operation. Although the city of Palermo in this district is the largest seaport and first city of commercial importance in Sicily, only a comparatively small quantity of the products are shipped from that point, this exportation going to England, that coming to the United States being confined to fresh fruit.

The industry in the Syracuse district.—The fourth by-product district is on the opposite side of the island, southeast of Palermo, and is but slightly less important than that center. The Syracuse district differs in many ways from the others of Sicily; the country not being mountainous, the fruit is cultivated farther inland than usual and the problem of irrigation is more difficult. Lemon culture is not the chief occupation here, for the country has been one of the finest wheat-growing regions since ancient times, and at present, besides this cereal, both almonds and grapes are extensively cultivated.

The climate is very mild, the gathering of lemons beginning several weeks earlier than in the other districts. October 15 to April 15 is a liberal estimate of the manufacturing season, while fifteen days might be cut from each end and more nearly represent the actual fact.

The district contains several isolated centers of production, the groves not being continuous, as in the lemon belt proper, but clustered in large groups about the several towns. Three of these centers are of considerable importance, the cities of Syracuse, Floridia, and Avola, all containing six or more factories and each employing twenty hands or more.

At Syracuse there are no factories on the island which forms the old city, all being on the mainland in the newer suburbs. Comparing favorably in size with the average factories in other districts, they are in equipment above those at Palermo, but not so well equipped as those near Messina. Floridia is some 12 miles inland from Syracuse, situated in a very fertile valley of lemon groves, the half-dozen factories here varying in size, two being of considerable importance; all are, however, devoid of mechanical

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

A CRUSHING MACHINE USED IN THE PREPARATION OF CITRATE OF LIME.

Mills are not used for extracting lemon juice in Sicily.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

A LEMON-JUICE PRESS.
This press acts also as a filter.

improvements. The output of this town is carted to Syracuse, as there are no railroad connections.

South of the city of Syracuse no lemons are grown until Avola, 15 miles distant, is reached. Here is situated another large group of orchards; the factories, as usual clustered about the town itself, are below the average size and have no special equipment. Some orange oil is prepared in this district and large quantities of peel are dried and sold for the preparation of the liquor, curaçao.[1]

The other centers in this district are Augusta, with one factory of average size; Priolo, with two small places; and Melilli, with one. Augusta is 18 miles north of Syracuse, on the coast, and is the center of the salt industry; Priolo is between Syracuse and Augusta, some miles from the railroad, while Melilli is farther inland, situated well up in the low hills.

The lemon products of the district find their way to market through Messina, with which there is direct railroad connection.

The industry in the north-coast towns.—The remaining district to be considered is the heterogeneous collection of towns on the north coast. Here, again, as in Palermo and Syracuse, the cultivation of the lemon takes place in isolated groups of orchards around the central towns, the country being very mountainous and having no cultivated strip of coast land, as on the south. The fruit is grown in the valleys between the spurs of hills, all of the large towns being near the Messina-Palermo railroad line, which winds along the seacoast.

By far the most important center, in fact the only important one of this region, is Barcelona, a small inland city not far from the seaport of Milazzo. Here are some three factories, employing from thirty to fifty hands each, and a few more of smaller size, all without mechanical equipment. The methods employed are, as has been stated, similar to those of the Palermo district, the old method of production being used and distilled oil manufactured from residues.

The small city of Patti, the next largest by-product center, is west of Barcelona, 2 miles from the railroad station of the same name. There are but two factories here, both employing approximately thirty hands and, as at Barcelona, producing considerable sweet and bitter orange oil.

Farther west there are no other factories until Capo d'Orlando is reached, at which place are several of small size, which is also the case at Santa Agata di Miletello. The factories in all of these places use the so-called new or two-piece method of manufacture, which is peculiar, inasmuch as they are situated between two large districts using the other method. At Santa Agata di Miletello the factories do not produce citrate of lime, the lemon juice being concentrated in copper kettles and sold to liquor and bitters manufacturers in northern Italy.

The commerce of the north-coast towns, as far as lemon by-products are concerned, is carried on through Messina, although there is a thriving local seaport town, Milazzo. While the district covers a much greater territory than that covered by either the Palermo or Syracuse districts, it produces less oil and citrate than either. The season is more nearly like that of the

[1]See p. 305.

Palermo district, although manufacturing begins somewhat earlier and ceases sooner than in that district.

MANUFACTURE OF CITRUS PRODUCTS

There are two chief by-products of lemon culture—the essential oil of lemon and citrate of lime; besides these, lemon peel in brine and concentrated lemon juice are of lesser importance. Oil of lemon is used very largely for flavoring purposes, it finds application also in perfumes and to a limited extent in pharmaceutical preparations; the greater part of that imported into the United States, however, is used in the preparation of the ordinary extract of lemon, well known to every housewife. Citrate of lime, or, more properly, calcium citrate, is an intermediate product in the manufacture of citric acid. In the lemon juice itself the acid occurs in the free state, together with sugars and mucilaginous bodies. It is in order to free it from these that it is combined with lime, for the compound thus formed is insoluble and precipitates from the juice, being finally separated by filtration. This product must then be again treated in order to free it from lime and obtain the citric acid once more in the free state. There were no factories in Sicily for this purpose in 1909, although the Italian government was, before the 1909 earthquake, making efforts to establish a plant by subsidy.[1] The product at that time was shipped to Germany, England, and the United States, where the lime salt was decomposed with sulphuric acid, filtered through boneblack, and crystallized from solution in water.

The salting of the lemon peel is usually confined to those districts of Sicily where the towns are upon the seacoast, situated near sloping beaches, so that sea water is easily obtainable. It is not usually packed in the interior, although a few towns near Messina have some little trade in this line, the product being repacked in that city. Producers in Sicily claim that there is a demand for three separate kinds of stock; first, that from which no oil has been removed; second, that which contains approximately half the oil; and, last, a completely exhausted product. All classes are consumed in the bakers' and confectioners' trades. Where the rinds are to be used for packing, the lemons are divided lengthwise, the pulp removed in the usual way, and the peel packed by hand as firmly as possible in large hogsheads, which are afterward filled with sea water and re-enforced by the addition of salt.[2]

The production of concentrated juice is not extensive, the factories being small and the methods of evaporation extremely crude. In those

[1] See pp. 146–50, 349, 354, 362.

[2] See pp. 110–12.

at Santa Agata di Miletello the juice is pressed from the pulp and filtered, as in the manufacture of citrate of lime, and then pumped into shallow tanks supported over a crude fireplace. Here evaporation takes place over a wood fire until the required consistency is obtained, this point being ascertained by cooling a portion of the juice and inserting a spindle. The final product, a very dark semi-syrup, of acid, bitter, and smoky taste, is sold to liquor and bitters producers in northern Italy. Besides the two factories at Santa Agata di Miletello, there are one or two on the Calabrian mainland. Altogether the industry is of minor importance.

EQUIPMENT OF FACTORIES

It has already been hinted that in the great majority of cases the factories in Sicily are very poorly, even crudely, equipped, the nature of the operations which take place requiring but very simple apparatus. In the preparation of oil, machinery is not used except in the few factories which are situated in Calabria.

For the manufacture of citrate, a crusher, as shown in Plate XVIII (left), a filtering device for juice and another for citrate, a precipitating tank supplied with a heating coil, an oven or heating room, and a small juice pump only are necessary. This apparatus is usually arranged to fit into quarters originally intended for other purposes; the crusher and filter presses on substantial foundations near the room where the cutting of the fruit takes place, near the latter a juice tank and pump, while the precipitating tank is also near by, as the pumping is usually done by hand in the heating room wherever convenient.

In many of the smaller factories a loft is floored off and the space thus provided used for extraction of the oil, the room often being scarcely 6 ft. high in the center, dark, and ill ventilated. On the north coast, where the work takes place at night (from midnight to 8 or 9 o'clock in the morning), this place also serves as sleeping-quarters for the sponge men. The custom of preparing the oil at night seems confined to the Palermo and north-coast towns. The explanation given for this method of operation is that the sunlight has a deleterious effect upon the oil, but a more probable cause is the fact that the sponging operation can take place at night with less trouble than any of the other processes in by-product manufacture and that the same workman can thereby work during both daylight and darkness.

PREPARATION OF THE FRUIT

The preparation of the fruit differs somewhat in the different districts, and while the variation seems slight it undoubtedly affects the length of

the operation and perhaps the quality of the oil produced. In the Syracuse, Etna, and Messina districts and in Patti and Santa Agata di Miletello, north-coast towns, a method known as the "two piece" is used. In Palermo and Barcelona the process used is called "three piece," although some factories in the latter city use the other method. The difference between the two lies in the manner of removing the rind from the fruit. In the former the lemon is halved and the pulp removed from these halves; in the other the peel is pared off in three longitudinal strips. The three-piece method of preparing the fruit is shown in Plate XIX (upper). When the fruit arrives at the factory it is dumped into large bins, around which sit the cutters, who divide the lemons in halves or pare them, according to the method used. An ordinary cheap kitchen paring-knife is used for this purpose, the operators being women, girls, and boys on the south coast; on the north coast women and children are seldom employed. The work is carried on very rapidly where the fruit is halved crosswise, the lemon being cut and tossed into the tub with a single motion of the arm. Where the peel is to be salted down, the fruit is divided from end to end, and the time consumed is relatively longer, as is also the case where it is pared. The next step in the process is naturally omitted where the latter method is used. The half lemons are thrown upon shallow troughs, on each side of which stand the operators provided with baskets for holding the peel. The instrument used consists of a sharp, slightly concave disk firmly fastened on the end of a stout sickle-shaped wire, provided at the opposite end with a wooden handle. The disk is skilfully slipped between the pulp and rind of the lemon, held in the left hand, and forced toward the end with a circular motion of both the instrument and fruit.

When sufficiently far advanced, a quick jerk removes the pulp, the separation being complete and the rind unbroken.

The operators are usually paid by the basket of resulting peel; in 1909 the women made from 20 to 40 cents a day, while the children, who do the cutting, rarely made over 15 cents, often as low as 5 cents. The prices now paid for this labor are higher as is shown on page 216. Where the lemons are pared the separation is much less complete, there being always considerable pulp left on the rinds and some little rind at the ends of the pared fruit. As a result of this, some little lemon juice becomes mixed with the extracted oil, and after the extraction of the oil from the peel the latter is therefore mixed with the fruit pulp from which citrate of lime is to be made.

This method is not practical in the United States because of higher wages.

EXTRACTION OF THE ESSENTIAL OIL[1]

In both methods of operation the peel is thrown into large wicker baskets, which, when full, are dipped into a reservoir of cold water and thoroughly shaken to remove the excess. This washing is said to wilt the rind and render a complete extraction of the oil possible. However this may be, it is certain that fruit treated in this manner and allowed to stand for several hours yields relatively more oil than that worked up immediately after separation from the pulp. At this stage, the pulp and peel having been separated, the former is sent to the crusher to be converted finally into citrate of lime, the latter to sponge men, who extract the oil.

The extraction by the sponging process is not essentially different with the different forms of peel, the operators sitting upon low stools with an earthenware bowl between the feet, a pile of peel in front of them, and a basket for the exhausted material at one side. The bowl is about a foot in diameter, provided with a deep lip, directly beneath which is a small, round, concave depression which serves when the bowl is tilted forward, in pouring out its contents, to hold back the settlings of juice and precipitated matter. Across the top is placed a stick so notched as to fit tightly on the sides; resting upon it are the sponges, which differ somewhat according to the manner of preparing the peel. Where the fruit is cut crosswise, a large, flat sponge is surmounted by a smaller concave one, shaped somewhat like a brimless slouch hat, the half lemon being placed within this sponge when pressed. When the lemon is cut in the other direction, a large, heavy sponge rests upon the flat one and the fruit is pressed, colored side down, into it. This method is also followed where the rind has been pared from the fruit. With the first method the half rind is held in the right hand between the thumb and first two fingers and inserted in the wide aperture of the concave sponge, whereupon the latter is pressed upon with the left hand, the weight of the body being thrown into the motion. The pressure is relieved, the peel turned partly over with the right hand, and the pressing repeated. The same operation is carried on once or twice more, the rind thus receiving three or four pressings. Where the concave sponge is not used, the peel or slices are pressed face downward on the other sponge with the right hand, the left being used to keep the sponge in place, the same amount of force and number of pressings being required in either case.

The sponging process is somewhat varied where the three-piece method is used, owing to the quantity of pulp left adhering to the rind. A shallow, glazed bowl is placed upon the one ordinarily used and the

[1]For physical and chemical properties, see pp. 21–36.

notched stick fitted to it so that the mixture of juice and oil is received directly here. At the end of the operation the sponges are thoroughly squeezed out by hand and the lemon oil separated from the juice by tilting forward the glazed bowl over the other and violently blowing the breath upon the surface of the mixture until the oil has been carried over into the lower bowl. In this operation some juice and residue are found mixed with the oil, and this is separated finally in the larger bowl by carefully tilting forward and repeating the blowing operation. The small amount of juice and residue now present is caught by the depression in this bowl and the oil is received in a measuring bottle. The operation where the two-piece method is used is very similar; the oil and what little moisture and residue are extracted are caught in the earthenware bowl and separated as indicated.

The oil in either case is allowed to settle for twenty-four hours or longer, filtered through paper, and stored in large copper containers; that made by the three-piece method is said to keep longer without becoming turbid.

TREATMENT OF THE RESIDUES

The treatment of the residues resulting from both methods is different; with the two-piece method they are passed through a conical cloth filter and the oil and water received in an earthenware bowl, where they are separated in the usual way. The filter is tied at the top and placed under a hand press, where the last traces of oil and water are expressed. The residues from the three-piece process, which are relatively greater in amount than by the other method, are placed in small copper stills, diluted with water, and distilled. The still is made in two parts, the pot being about 2 ft. high, narrowing abruptly to a 3-in. aperture at the top, over which the condensing part fits tightly, the joint being cemented each time with clay. The latter part is a basin, whose straight sides are continued a short distance beyond the concave bottom, after which they converge similarly to the sides of a funnel. It is provided with two spouts, one of which enters under the bottom into what becomes the condensing chamber of the still; the other enters above and is used to draw off the water placed in the basin in order to cool the vapor coming in contact with it during the distillation. The condensation is further aided by wrapping the other spout with rags, over which the attendant pours cold water from time to time.

The oil obtained by this process is water white, of disagreeable odor and abnormal chemical characteristics; having no sale in the pure state it is invariably mixed either by producer or broker with the hand-pressed product. The filtration method undoubtedly gives the best results, for

if the residues are treated immediately the resulting oil can scarcely be distinguished from the original. Distilled oil is produced only at Barcelona and Palermo; in all other districts the residues are filtered.

MACHINE-MADE ESSENTIAL OIL

The manufacture of lemon oil by machine is confined to the mainland of Italy, in the province of Calabria. As has been said, large amounts of bergamot oil are made here, and it is with the machine used in this industry that lemon oil is produced. The bergamot is shaped more like an orange than a lemon, being nearly round, so that the apparatus has to be slightly modified in order to use it on the latter fruit. The modification consists in removing the flat disks and substituting concave ones for them.

The machine itself, shown in Plate XX (left), consists of a stand supporting two upright arms united by a cross-beam at the top. On the inside of one of these uprights is hung a large cogged wooden fly wheel geared against a cylinder, the sides of which are upright spokes fitting into the cogs of the fly wheel. To the under side of this cylinder is bolted a corrugated disk, shown in Plate XX (right), fitted so as to revolve above a like stationary one at the bottom of the machine. An arrangement for raising and lowering the upper disk is provided for by an arm fastened to the cylinder and extending over a cross-piece at the rear. This arm is so weighted as to regulate the pressure brought to bear upon the fruit which is placed between the upper and lower disks. When it is lowered, the upper disk is raised and the lemons, which must be of uniform size, are placed within. The lever is then raised, lowering the disk upon the fruit, and the outside fly wheel is turned by hand. After two minutes it is stopped and the fruit removed, each lemon being carefully wiped off with a sponge. The grated rind and oil are received in a large pan set beneath the machine and subsequently filtered through cloth filters, the residue being placed under hand presses to express the last traces of oil and moisture.

Oil manufactured in this way is not in the least inferior to the hand-pressed product and has the added advantage of a much richer color, being used chiefly for the purpose of bringing up the color of the latter. The machine is not used on lemons until after the close of the bergamot season, lemons ripening before that time being sold to Sicilian buyers.

CITRATE OF LIME[1]

After the pulp of the lemon has been removed from the rind it is conveyed to a crusher, sometimes power-driven, but in a vast majority

[1]See pp. 149–50.

of factories run by hand. A crushing machine is shown in Plate XVIII (left). The ordinary type consists of a hopper leading into wooden rollers and a small chute for carrying off the crushed pulp, the whole being placed over, or very near, a juice tank, into which the drippings flow. The crushed pulp is shoveled into large, circular, straw filtering-mats and pounded down firmly with wooden rams. These mats are closely woven of coarse straw and have a circular opening at the top; after being filled they are placed one upon another in stacks of four to twelve under hand presses of large size. The presses are set, often by the aid of a windlass, and the combined pressing and filtration proceeds until the flow of juice ceases, the presses being set down several times during the operation. A press and filtering-mats are shown in Plate XVIII (right). The juice is led into the juice tank, from whence it is pumped, usually by hand, into a large vat provided with suitable heating arrangements consisting of direct fire, steam coil, or, in one or two instances, leading steam directly into the juice. In this tank the acidity of the juice is neutralized by means of lime water, the point of neutrality being ascertained by the use of litmus paper, and after heating for several hours the juice is run off into the filtering tank while still hot. The latter tank is provided with a false bottom of wooden latticework, over which is spread a special filtering-cloth; the citrate of lime, which is deposited in a voluminous white powder, is retained by this cloth, while the waste liquor runs through and is discarded. When this liquor has sufficiently drained off, the deposit is shoveled into a small filtering-bag and placed in stacks beneath a small press, where the excess is further removed. It is usually readily removed from these sacks to iron pans in which it goes to the drying oven. This oven is a small room, ventilated at the top, around the sides of which are built tiers of iron frames for holding the pans. In the center of the room is a gigantic charcoal burner, which supplies the heat for the evaporation, from six to forty-eight hours' drying being necessary, depending upon its size. The thoroughly dried cake, containing over 60 per cent of citric acid, is broken into small pieces and packed in hogsheads holding about 675 lb. each. An interior view of a by-product factory is shown in Plate XIX (lower).

The method of disposing of this product is very similar to that used with essential oils; small or large lots are offered to brokerage firms, accompanied by a certificate of analysis showing the actual content of citric acid. Exportation is nearly always through one of these houses, and there seems to be little or no effort to market the output co-operatively. The product is purchased on the citric-acid content by the large chemical supply houses in Germany, England, and the United States.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

PARING LEMONS, THREE-PIECE METHOD, PALERMO, SICILY.

This method is used only in the Palermo district and at Barcelona.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

INTERIOR OF LEMON PRODUCT FACTORY, SYRACUSE, SICILY.

This shows one of the few factories in Italy using mechanical devices for handling the fruit.

COSTS OF PRODUCTION

The quantity of the by-products obtained from a given number of fresh lemons will depend upon the quality of the fruit, the season of the year, the time which has elapsed between the gathering and working up, and the efficiency of the latter process. When allowed to ripen upon the tree, the lemon loses a considerable part of its acidity and the oil is also less in quantity and of an inferior grade. Where the fruit is broken or bruised in handling, the yield of oil is diminished, and this is also the case where a number of days are allowed to elapse between picking and working up. The content of citric acid is not lessened by these faults, however. On the average quality of fruit, 100 lb. of oil and 675 lb. of citrate of lime, containing 430 lb. of citric acid, can be produced from 100,000 lemons. The average price for these substances varies from $80 to $100 for the oil and $75 to $95 for the citrate.[1]

The cost of production is very difficult to estimate and will, of course, vary in every locality and almost with every factory. In the consular reports of the late Dr. Cheney he estimates the average value of lemons to the grower in Sicily in 1908 at $150 per 100,000. The fruit going for by-products is the lowest grade, however, and according to Chace and Powell in 1909 did not average over $100 per 100,000, leaving a gross profit to the by-product producer at that time of from $50 to $100. One sponge man can produce between 2 and 3 lb. of oil per day, for which he then received about 30 cents, making the cost of extracting the oil from 100,000 lemons from $10 to $15. Other processes about the factory are much cheaper, and, at the prevailing wages of workmen in 1909, $5 to $10 additional was a liberal estimate for other expenses, leaving a profit of from $30 to $70 jointly on 100 lb. of oil and a pipe of citrate of lime.

The cost of production of both lemons and lemon products more than doubled between 1914 and 1919. The wages paid fruit packers in 1914 was 3.60 lire ($0.69) per nine-hour day; in 1919 8 lire ($1.64) per eight-hour day, and 1.20 lire for every hour overtime. Packers agree to pack not less than five boxes per hour or forty boxes per day, but rarely pack more than thirty to thirty-two boxes.

Fruit pickers in 1914 received 3 lire for a ten-hour day, while in 1919 they received 8 lire for an eight-hour day.

Farm laborers such as tree pruners, etc., formerly were paid 3 lire per day, while in 1919 they secured 10 lire per eight-hour day.

Freight rates, on the other hand, have been kept rather low, particularly those to New York—$0.54 a box. The rate to England is $1.37

[1]See pp. 349, 353, 362, 363, 366–68, 372.

a box. The high rate of exchange against the Italian lira since the war has also been of benefit to the lemon exporter.

The cost of boxes and barrels has more than doubled since 1914 while the cost of containers for essential oils is almost prohibitive, as these containers are made of copper.

The comparative costs of lemon product production between the United States and Sicily are found in chapter xi, on pages 213–14.

VARYING TRADE SYSTEMS—SPECULATION

The methods of conducting the very important trade in lemon products varies in the different provinces of Sicily, that prevailing in the province of Messina being especially worthy of description, because through the port of Messina by far the larger portion of the lemon derivatives of the island is exported. Thus, statistics show that of the total exports of citrate of lime and concentrated lemon juice, there were exported through Messina 75 per cent in 1906–7. Messina also exports an average of 77 per cent of the total exportations of essential oils of the kingdom.

The system which has been in vogue in Messina province for many years depends on a series of advances, extending from the merchant, or actual exporter, down, through the manufacturer to the orchard owner, or grower of the lemons. The latter is usually not engaged in the manufacture of lemon derivatives, but sells his fruit outright on the trees, generally months before maturity. Thus a typical transaction would be as follows: The manufacturer goes to the merchant, or exporter, and contracts to furnish so much citrate of lime, of a certain standard quality and perhaps with the same firm, so much essential oil of lemon. He then receives on the spot a certain percentage of the agreed price (usually about 25 to 30 per cent), with which he in turn pays an advance to secure the entire crop of an orchard, or only contracts for a supply of refuse lemons, and is able to partly defray expenses of manufacture. Upon delivery of the goods he is either at once paid the balance of the fixed price, less a fair rate of interest on the money advanced, or receives a further percentage, the balance to fall due some months later, or when the goods are finally sold for export, according to the nature of the contract. This advance system obtains in all the provinces of Sicily and in Calabria. Naturally the merchants who give the advances are in return given the preference in the sale of the goods.

Lemons are usually sold by the thousand; essence, or essential oil of lemon, by weight, in copper containers of, generally, 1, 5, and 25 lb. capacity; citrate of lime in pipes containing 305 kilos (672 lb.).

Under the influence of speculation during "boom" periods, especially marked in 1907, prices of citrate of lime and of oil of lemon may be suddenly forced up and artificially maintained, without any sound commercial reason. It is this speculation which, it is claimed, more than anything else, precipitated the disturbed state of affairs in 1909.

On July 8, 1903, a law was passed, whereby certain banks were authorized to make advances up to two-thirds of the ruling market value of lemon derivatives against certificates of deposit of goods. Upon this three corporations were formed in Sicily, whose scope and object, according to their charters, were to prevent speculation, to endeavor to keep prices steady, and to establish a minimum price whereby all branches of the trade might be enabled to conduct a prosperous business. These corporate bodies were known as "Societa di-Acireale," "Societa Sicula" and "Societa di Palermo." For some time these societies did good work in assuring to their members a certain minimum price, and abstained from speculation, but in 1907, noting the large profits being gained by outside interests, they abandoned their conservative methods and sought to also enter the speculative field. Buying, especially citrate of lime, at steadily increasing prices and holding on to their purchases in the hope of still greater profit, the speculators were caught at the time of the financial crisis in the United States with a considerable stock which they were unable to dispose of. At the close of the year, instead of a normal stock of a few hundreds the purchasers had on hand some 3,000 pipes of citrate of lime. This large surplus had been accumulated at prices ranging from 700 to 750 lire ($135.10 to $144.75) per pipe, and the fall in the market inflicted serious losses on the societies. Still worse was the plight of individual speculators, some of whom, it is said, lost absolutely all they possessed in the great and rapid depreciation of values.

To illustrate the fluctuation to which the market has been subject, the following statement showing the average prices of citrate of lime for nine years is given, the prices reduced to United States currency, being per quintal of 220 lb.: 1889, $26.25; 1900, $24.12; 1901, $25.28; 1902, $20.10; 1903, $22.20; 1904, $24.12; 1905, $26.05; 1906, $32.81; 1907, $42.46. Later prices are listed on pages 353, 362.

Oil of lemon in 1907 reached a price of over 97 cents per Sicilian pound (12 oz.); in 1909 it was about 40 cents.[1]

THE 1908 LAW FOR THE CENTRALIZATION OF THE TRADE

A law was enacted on June 5, 1908, whereby a Citrus Fruit Chamber (Camera Agrumaria) was established, the object of this being to central-

[1]For further discussion and prices, see pp. 235–39, 349, 363, 372.

ize the sale of citrate of lime and lemon juice under the direct control of the Chamber, making all goods not sold through the Chamber subject to a tax, estimated at 25 to 30 per cent of the normal value, whereas goods sold to the Chamber only pays a commission of 2 per cent. The effect of this obstacle to the unrestricted interchange of goods, the consequences of which was not foreseen by the trade, was to stop the usual advances hitherto given by the merchants. It is to be noted that the Chamber was not to make any such advances until the goods were actually delivered; indeed it would not be financially able to do so, as it only had a capital of about $40,000; while the merchants, in the aggregate, employed a capital of many times as much in making these advances before delivery. The number of manufacturers of citrate in Calabria and Sicily is about 250, the majority of whom possess but limited capital, and their competition contributed considerably to keep up the prices of lemons. Not being able to buy for lack of advances, the number of purchasers of refuse fruit diminished, and it is claimed that this law injured these manufacturers and indirectly the lemon growers.

According to the treaties of commerce between Italy and Germany, Austria-Hungary, and Switzerland, Italy is bound to lay no export tax on its products. The tax, therefore, in favor of this Chamber was laid in the form of a tax for analysis, the legality of which was questioned. This seemed an evasion of the treaties with the countries mentioned. The treaty with the United States contained the "most-favored-nation" clause, and the legality of the foregoing tax might have therefore been contested.

Victor Emmanuel III, By the Grace of God and by the Will of the Nation King of Italy.

The senate and the Chamber of Deputies have approved: We have sanctioned and do promulgate as follows:

ARTICLE I

A Citrus Fruit Chamber (Camera Agrumaria), with its seat at Messina, is established, which has for its scope the protecting and furthering of the interests relating to the production of, and commerce in the citrus fruits and the facilitating of the manufacture of, and trade in the citrus-derivatives. To which end the following functions are accorded to the Chamber:

(*a*) To study and promote the provisionary measures for the development and regulation of the commerce in the citrus fruits and their derivatives;

(*b*) To undertake and furnish to interested parties information regarding the conditions of the principal markets and regarding the quantity of fruit in situ or in transit;

(*c*) To facilitate and further the direct relations of exchange between the producers and consumers of citrus fruit and derivatives;

(*d*) To develop the consumption of the derivatives of citrus fruit, seeking for them new outlets, or new uses or applications;

(*e*) To guarantee by issuance of certificates of analysis, given by chemical laboratories of the citrus fruit chamber or by others recognized by the same, the

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

A LEMON-OIL MACHINE USED IN CALABRIA.

This machine is confined in its use to the Calabrian district, where it is also employed in the production of bergamot oil.

(*Powell and Chace, U. S. Dept. of Agric. Bull. 160*)

DISKS USED IN CALABRIAN MACHINES.

The surface of these disks is somewhat similar to that of a burr-mill.

genuineness and the quality of the citrate of lime and of the concentrated juice produced in the kingdom, whether for internal consumption or for exportation;

(*f*) To attend, for account of the producers who may make request for it, and in the forms established by this law, to the sale of citrate of lime and of concentrated juice which has been delivered to said Chamber for that purpose by the producers themselves;

(*g*) To promote, wherever necessary, the establishment of general store-houses for the citrus-derivatives in the centers of production which are unprovided with such store-houses;

(*h*) To make advances upon the deposits of citrus-derivatives or upon certificates of deposit of the derivatives themselves in the general store-houses, within the limits and in accordance with the regulations laid down by this law;

(*i*) To promote and facilitate the establishment and operation of factories for citric acid, candied fruits and other products derived from the citrus fruits;

(*l*) To promote the formation of a citrus fruit Bank, which may make advances upon deposit to the citrus producers and manufacturers.

The functions of the Chamber as detailed in Sections "*e*" and "*f*" may be, by royal decree, extended to other derivatives of the citri.

ARTICLE II

There are established five sections of the Citrus Fruit Chamber whose seats shall be, respectively, in Palermo, Catania, Messina, Siracusa and Reggio, Calabria.

Each section is composed of three members chosen among the larger producers of citrus fruit, two nominated by the provincial Deputation, and one by the local Chamber of Commerce.

Until it shall have been otherwise provided by special laws to be presented by the 30th of June, 1909, for the organization of elected representation by an assembly of delegates of the producers, the Chamber shall consist of nine members, of whom five shall be chosen respectively by the sections from among their own members; the other four shall be chosen by the Minister of Agriculture, Industry and Commerce from the class of the citrus cultivators after hearing from the issue Banks.

The members of the sections and of the Citrus Fruit Chamber must possess Italian Citizenship.

In case the appointments are not made by the time established by the Minister of Agriculture, Industry and Commerce, the same Minister shall provide for the nomination of the counsellors.

The counsellors, thus nominated, shall elect from among themselves by secret ballot and absolute majority of votes, the president and vice-president.

ARTICLE III

The office of counsellor of the Chamber is gratuitous.

The Chamber shall appoint a technical manager, a secretary and the other requisite employees for its operation, within the limits of the plan to be approved by the Minister of Agriculture, Industry and Commerce, by whom moreover the salaries for the said force must be approved.

ARTICLE IV

Commencing with the fifteenth day following the first formation of the Chamber, citrate of lime and concentrated juice shall not be admitted for transport upon the railroads or for shipment in the ports of the Kingdom, if they are not accompanied by a certificate of analysis issued by the Citrus Fruit Chamber.

Exception is made for shipments sent to the magazines appertaining to the said Chamber, or made in view of transportation or concentration of the products in magazines in which the said products are to remain while awaiting sale for consumption or for exportation. In these cases the circulation of said products must be effected according to the instructions which shall be established by the rules of administration for assuring the payment of the Chamber tax, in accordance with Article II, when they may be sold for consumption or exportation.

ARTICLE V

Whoever produces citrate of lime or concentrated juice or trades in these products, may entrust the sale to the citrus chamber, depositing the merchandise either in the magazines of the respective sections, or in another one of the Citrus Fruit Chamber, or in the general magazines authorized by said chamber to take delivery of the merchandise for its account.

The sale is made by the Chamber for account of the depositors, according to the order of precedence in which the merchandise was delivered.

At the commencement of each trading year the Chamber establishes the minimum valuation of the merchandise for the entire season; this valuation marks the minimum price of sale below which the Chamber can not cede the goods.

The proceeds are liquidated, in favor of the several depositors, at semi-annual periods and in equal measure for all, according to the rules for computation which shall be determined by the rules of administration.

ARTICLE VI

To the Citrus Fruit Chamber is transferred, as first capital and without obligation of reimbursement, the sum of lire 200,000 ($38,610) to be levied upon the sums set aside in the expense budget of the Minister of Agriculture, Industry and Commerce, based upon the law of July 11, 1904, No. 376.

With said sum and with the proceeds of the tax provided by Article XI, the Citrus Fruit Chamber is authorized to make the advances upon certificates of deposit of the citrus-derivatives in the general magazines, subject to the dispositions of Article XII.

ARTICLE VII

The said advances are made in the proportion of two-thirds of the value of the citrus-derivatives.

Upon these advances interest is due at the rate of not exceeding four and one-half per cent from the date the advance has been made to that of sale.

ARTICLE VIII

The Banks of issue are authorized to discount, at a special rate, in the proportion established by the preceding Article, and according to the terms of Article XXX of the unified text of laws upon the before mentioned Banks, modified by the law of December 31st, 1907, No. 804, the warrants of the citrus-derivatives, upon whose certificates of deposit the Citrus Fruit Chamber may have made advances, subject to the dispositions of Article XII.

ARTICLE IX

At the time of effecting the advances upon the goods delivered to the Chamber for sale, the Chamber itself shall cause the analytical examination of them to be made. After the advance has been made, the goods are understood to be definitely delivered for sale.

ARTICLE X

When the goods of each depositor are sold the Chamber pays on account the portion of the price which remained after the advance, thus completing the payment of the minimum price of the annual valuation.

The liquidation of the actual price of sale shall be made at the end of each half-year, that is, on June 30th and December 31st, of each year, upon the basis of the actual net profit of sales made during the half-year.

ARTICLE XI

Upon the citrate of lime and upon concentrated juice, for which the certificate of analysis is requested for transport upon the railroad or for shipment, in accordance with Article IV, the Chamber collects a Chamber tax, the proceeds of which are destined to defray the expenses of administration and others dependent upon the disposition of this law and to contribute to the formation of the capital of the Chamber.

For the products not entrusted to the Chamber for sale, the chamber tax is liquidated and exacted upon the certificate of analysis, based upon the quantity for which the certificate itself is issued and in the maximum proportion of lire 0.60 ($0.116) per quintal (220 lbs.) and per each per cent in grams of citric acid, adding together the free citric acid and the combined citric acid.

The chamber tax upon the products sold by the said Chamber for the account of the respective owners is exacted by levying 2% upon actual net proceeds of the sale. No other sum may be levied upon the sale price, the ware-house charges and also the cost of analysis being understood to be covered by the said levy.

The Chamber may also sell on the spot. In this case there shall not be due by the purchaser, even though he may wish to export, at the time when the certificate is issued to him, the tax provided in this Article, which shall be understood to be included in the price.

The certificate of analysis must in every case be visaed in exemption of stamp dues or every other expense.

ARTICLE XII

From the proceeds of the before mentioned tax 20% shall be put aside and paid in to the Bank of Sicily on current account bearing interest and mortgaged in favor of the Banks which have made the advances, in the guarantee of the full payment of their credits arising from the operations made by them under the terms of this law.

ARTICLE XIII

In case of proven irregularity in administration or the inobservances of the dispositions of this law and of the rules of administration as in Article XVI, or upon the ascertained impossibility to operate, the Citrus Fruit Chamber may be dissolved by royal decree upon proposal of the Minister of Agriculture, Industry and Commerce.

In case of dissolution, the administration is entrusted to a Government commissioner until the installation of a new council for which a limit of not exceeding three months shall be fixed.

ARTICLE XIV

Disputes between the chamber and whoever may have entrusted to it the sale of citrus-derivatives in accordance with Article V, shall be decided without appeal by three arbitrators. For this purpose there shall be formed a body of six arbitrators, of whom three shall be experts in legal matters and three experts in citrus fruit matters, nominated and if necessary surrogated, two by the Minister of Agriculture, Industry and Commerce, two by the first President of the Appellate Court of Palermo and two by the chamber.

In the decision of each individual case there may not intervene more than two experts of one category, or more than one of those nominated by the chamber.

The selection of the arbitrators shall be made the first time by lot and thereafter by turn.

The costs of arbitration shall be borne by the party against whom judgment is given.

ARTICLE XV

To the industrial establishments for the working up of citrus, the candied citrus included, and for the production or transformation of the citrus-derivatives, which shall be founded in Sicily or in the Province of Reggio, Calabria, within the period of ten years from the date of this law, and to those already existing, that may be enlarged or transformed within the said period of time, for the increase of the production or transformation of said derivatives, are respectively extended the privileges accorded to new or enlarged establishments in the Commune of Naples, according to Articles VII, VIII, XII, XIII and XIV of the law of July 8th, 1904, No. 351.

ARTICLE XVI

Within two months from the day of its installation the chamber must submit for approval to the Minister of Agriculture, Industry and Commerce, its own rules of administration.

The rules shall determine:

(*a*) The rules for internal administration.

(*b*) The powers and responsibility of the president and of the several administrators.

(*c*) The rules for the nomination and the eventual dismissal of the technical manager, of the secretary, and of the other employes.

(*d*) The rules for the computation of the final liquidation of the price obtained from the citrus-derivatives delivered for sale to the chamber, and whatever else may be necessary for the easiest attainment of the objects for which the chamber is established.

These rules of administration shall be approved by royal decree upon proposal of the Minister of Agriculture, Industry and Commerce.

By the same royal decree shall be established the rules for the governmental supervision of the administration and the working of the chamber and the penalties for the violation of the dispositions of Article IV.

By royal decree shall be fixed the day, when the Citrus Fruit Chamber is understood to be established for the effects of Article II.

Such day can not be earlier than September 1st, 1908.

By the same decree the relation between the functions of the sections and those of the Citrus Fruit Chamber shall be regulated.

ARTICLE XVII

The chamber shall bank with the Bank of Sicily under the conditions and rules which shall be established by the rules of administration as in the preceding Article.

ARTICLE XVIII

By royal decree there may be established a term of less than two months for the notice required for the working of the citrus general store-houses in conformity to the relative law.

ARTICLE XIX

When the capital of the Citrus Chamber, as in Articles VI and X, shall have reached the sum of one million (lire) upon the ulterior net profits, the chamber shall set aside annually 20% for granting aid for sickness and old age to the citrus fruit operatives. The relative amounts shall be paid in semi-annually to the national institution for aiding in sickness and old age of workmen (National Aid Institution, Cassa Nazionale di Previdenza), which shall administer the relative sums according to the contract which shall be established between said Cassa and the Citrus Fruit Chamber.

ARTICLE XX

In case of the suppression of the Citrus Fruit Chamber the capital accumulated in the period of its activity shall, by royal decree, proposed by the Minister of Agriculture, Industry and Commerce, and after the Council of Ministers has been heard, be devoted in favor of citrus production, and employed in the manner which shall be judged most useful, and which shall be established by special law.

TEMPORARY REGULATIONS

ARTICLE XXI

Commencing from the day in which the Citrus Fruit Chamber shall operate until the 31st of August, 1909, the citrate of lime and concentrated juice which will be deposited with the said chamber shall not enjoy, as to obligations toward the respective depositors, the precedence laid down in the second section of Article V; and the proceeds of the sale shall be distributed among all the depositors in proportion to their respective deposits.

(*La Parfumerie Moderne*)

ORANGE GROVE AT NABEUL, TUNIS.

(*La Parfumerie Moderne*)

COLLECTING ORANGE FLOWERS AT NABEUL, TUNIS.

The first liquidation shall be made December 31st, 1908. The second August 31st, 1909.

We order that the present, under the seal of State, be inserted in the official list of the laws and decrees of the Kingdom of Italy, commanding all whom it may concern to observe the same and cause it to be observed as a law of the State.

Dated at Rome, the 5th day of July, 1908.

(Signed) VICTOR EMMANUEL.
F. Cocco-Ortu,
Carcano,
Lacava.

Visaed, The Guardian of the Seal, Orlando.

THE SICILIAN CITRATE AND SULPHUR INDUSTRIES COMPARED

Until recent years Sicily was the most important factor in the world's supply of sulphur as well as lemon products. The Sicilian sulphur industry has now been displaced by the American industry which has developed large production owing to the easy extraction of sulphur from Louisiana and Texas mines. The history of the sulphur industry is of interest in connection with the lemon products industry because of the parallel which may be drawn between the histories of both. Both were Sicilian monopolies, both were formerly controlled by the Sicilian government, and both show clearly the false economic basis involved.

The production of sulphur in Sicily rose from 1860 to 1905. Since 1919 production has decreased while the American output has increased.

The average price of sulphur from 1860 to 1876 was such as to encourage exploration and production. As a consequence other fields of sulphur were opened and the price gradually diminished. The Sicilian government formed a compulsory syndicate in 1906 in which all Italian producers were required to combine for twelve years. The object of this syndicate was to fix the price of sulphur periodically and to limit production. The company made a private agreement with a United States company as to the division of foreign fields for the marketing of sulphur. During the world-war sulphur was in great demand for ammunition, and owing to lack of tonnage American sulphur shipments to Europe were curtailed. The Italian government commandeered the sulphur trade and the American agreement terminated. Now that freights are again normal American sulphur is everywhere underbidding the Sicilian.

At the time that the Italian government passed the law for the control of the citrate of lime trade in 1908, Sicily was almost the sole source of the world-supply of citric acid. The prices established by the syndicate were such as to arouse and stimulate the manufacture of citric acid elsewhere, notably in the United States and in the Hawaiian Islands. As

a consequence the syndicate began to sell citric acid for less than the fixed price to producers. To 1925, the loss to the government is given as approximately 80,000,000 lire. The Italian government then had on hand about 18,000 tons which is as much as the world can consume in three years.

The government has now discontinued the fixed price to the producers and is to market the accumulated material over a period of years. This marketing, gradual though it be, will each year represent a carry-over, and this cannot fail to depress the domestic price. The result will be that the industry which was artificially and unwisely stimulated with public money will face a period of distress that would not have taken place if the business had remained in private hands.

CITRUS FRUIT EXPORT DATA[1]

The Italian export trade in citrus fruit has suffered several reverses in recent years. From an average annual production of 882,000 short tons during 1909–13, production has dropped to 634,000 short tons dur-

TABLE LXV*

ACREAGE† OF CITRUS FRUITS, 1913, 1921, AND 1922

	1913	1921	1922
Uncultivated	153,696	149,743	149,743
Cultivated	114,160	118,114	117,867
Total	267,856	267,857	267,610

*_Notizie Periodiche de Statistica Agraria_, June, 1923, p. 219; April, 1922, p. 156; April, 1914, p. 165.
†In acres.

ing 1921–23. Lemons dropped from 441,000 short tons annually to 331,000 and oranges and mandarins from 358,000 to 303,000 metric tons. Exports of all fresh citrus fruits before the war averaged 441,000 short tons, but fell to 254,000 short tons for 1921–23.

In a report dated April 1, 1924, the American Consul at Rome brings out the fact that while greater development of the citrus industry in America has cut Italian business severely, the expansion of that industry in South Africa and Australia offers more severe competition. While the American duty of two cents per pound on imported lemons is a serious consideration, the ability of the countries in the Southern Hemisphere

[1]Because the lemon products industries are related to the amount and condition of the lemons grown the following information is included.

to put fruit on the market during the European summer is an even worse blow to Italian growers. With regard to the American trade the annual

TABLE LXVI*

PRODUCTION† OF CITRUS FRUITS, 1913, 1921, 1922

	1913	1921	1922
Total citrus fruits	1,932,332	1,353,404	1,493,396
For provinces in which the greatest production occurs:			
Lemons	948,860	677,694	764,555
Oranges	906,532	615,083	659,396
Mandarins	69,445	48,722	55,776

*_Notizie Periodiche di Statistica Agraria_, June 1923, p. 219; April, 1922, p. 156; April ,1914. p. 165
†In 1,000 lbs.

TABLE LXVII*

LEMONS: EXPORTS FROM ITALY BY COUNTRIES, CALENDAR YEARS, 1898–1923
(1,000 Boxes. 1 box=84 lbs.)

Year Ending December 31	United States	United Kingdom	Austria Hungary	Russia	Germany	Turkey in Europe	Netherlands	Australia	Canada
1898	1,602	908	557	246	182	89	79	36	34
1899	1,609	881	951	300	240	139	87	32	7
1900	1,075	814	821	314	218	108	112	50	41
1901	1,284	1,099	806	478	236	54	129	50	53
1902	2,057	1,407	1,051	358	469	35	140	41	73
1903	1,705	1,221	1,247	468	392	47	99	45	28
1904	2,280	1,130	1,352	375	436	73	96	29	38
1905	1,731	1,036	1,141	382	561	41	60	39	59
1906	2,431	1,243	1,126	461	645	74	50	48	7
1907	2,521	1,180	1,169	411	688	100	62	23	10
1908	2,101	1,165	1,254	687	616	77	84	20	23
1909	1,974	1,314	1,329	545	762	172	73	51	43
1910	2,139	1,318	1,250	510	714	237	75	36	57
1911	1,933	1,380	1,232	472	829	230	82	29	65
1912	1,992	1,217	1,101	551	1,083	18	45	36	53
1913	2,916	1,143	1,271	674	1,070	162	68	54	72
1914	3,051	1,396	1,193	568	996	262	72	48	26
1915	1,856	1,137	441	309	355	3	332	27	2
1916	1,730	1,065	.....	30	.....	.....	16	13	13
1917	1,228	676	.....	1	.....	.....	.....	3	24
1918	942	918	.....	.....	.....	.....	.....	†	7
1919	1,023	713	93	42	55	91	40	3	9
1920	1,465	522	491	1	547	147	19	4	3
1921	‡	.....	.....	.....	.....	.....	.....	.....	.....
1922	1,301§	.....	.....	.....	.....	.....	.....	.....	.....
1923	1,487§	.....	.....	.....	.....	.....	.....	.....	.....

*Compiled from *Movimento Commerciale Del Regno D'Italia.*
†Less than 500 boxes.
‡Reported in value only in reports of Bureau of Foreign and Domestic Commerce.
§Imports into the United States as taken from reports of Bureau of Foreign and Domestic Commerce.

TABLE LXVII—*Continued*

Year Ending December 31	Argentina	Roumania	France	Belgium	Switzerland	Denmark	Norway and Sweden	Egypt	Other Countries	Total
1898.....	33	26	25	19	15	7	5	1	11	3,875
1899.....	16	24	46	18	19	6	11	5	7	4,399
1900.....	25	13	43	30	19	1	11	2	12	3,709
1901.....	27	24	59	32	27	7	6	2	17	4,390
1902.....	15	30	51	34	19	10	9	10	25	5,834
1903.....	16	35	39	50	28	19	1	4	28	5,472
1904.....	15	28	87	65	39	35	17	8	18	6,121
1905.....	23	18	119	56	56	13	17	17	23	5,392
1906.....	19	54	159	67	67	22	29	40	12	6,554
1907.....	36	89	94	68	46	72	17	58	17	6,661
1908.....	31	13	64	72	83	19	24	81	18	6,432
1909.....	36	34	87	93	63	51	32	45	16	6,720
1910.....	32	33	67	62	74	74	24	59	18	6,779
1911.....	60	19	113	115	88	53	39	24	26	6,789
1912.....	29	83	77	126	83	56	73	40	74	6,737
1913.....	38	94	56	105	78	71	64	20	49	8,005
1914.....	20	55	55	107	77	43	42	23	60	8,094
1915.....	40	52	107	..	448	108	48	24	91	5,380
1916.....	36	..	97	..	2,193	164	56	36	57	5,506
1917.....	26	..	236	..	1,647	4	2	23	74	3,944
1918.....	†	..	433	..	40	..	..	8	46	2,394
1919.....	22	53	285	32	948	39	18	5	170	3,641
1920.....	43	137	210	65	164	10	19	20	172	4,039
1921.....	..	..	..	..	..	..	..	..	..	4,155
1922.....	..	..	..	..	..	..	..	..	..	3,567
1923.....	..	..	..	..	..	..	..	..	..	3,699

†Less than 500 boxes.

average for 1909–13 of 103,000 short tons of lemons fell away during 1922–23 to only 43,000 short tons, with all indications pointing to further shrinkages. The loss of former markets in Central and Western Europe through economic collapse of those markets is felt very severely. Normally 55 per cent of Italy's acid fruit exports went to Central Europe and Russia. France and Switzerland have increased their takings, but the aggregate is a very small proportion of the former Europe trade. These factors, coupled with indifferent and backward methods of cultivation and marketing at home, indicate a very discouraging outlook for Italian citrus fruit.

It will be noted that the production of lemons, oranges, and mandarines in the principal provinces of Italy is practically the total production of citrus fruits. Some fruit is produced in provinces other than those included in the total for the various classes of citrus fruits, but this production is relatively unimportant.

Lemon imports into the United States show considerable quantities coming from the United Kingdom and Germany. These are evidently re-exports of Italian or Spanish lemons.

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CHAPTER XVI

THE INDUSTRY IN ASIA AND ASIA MINOR

JAPAN

The principal fruit grown in Japan is the orange. During the five-year period, 1909–13, the total number of orange trees in Japan averaged 20,310,000 annually, and produced 501,000,000 lb. In the same period mandarins were exported to the annual extent of 24,729,000 lb. valued at $460,000. A large part of these were sent to Asiatic Russia. Candied kumquats are made here as well as in China.[1]

The districts which produce practically all of the citrus fruit in this country are: Shiznoka-Ken, Hiroshima-Ken, Wakeyama-Ken, and Yokushima-Ken. All are situated in the southern and eastern parts, as farther north the climate is very cold and severe in the winter.

Statistics for Japan are given in Tables LXVIII and LXIX.[2]

TABLE LXVIII

STATISTICS FOR JAPAN

Varieties	Trees	Yield (lb.)
Navels	1,849,240	20,791,665
Mandarines and tangerines	4,102,338	99,407,400
All other citrus*	2,791,153	43,051,235

*Including lemons and bitter orange, used as grapefruit.

TABLE LXIX

Value Yens*	Boxes (California Standard)†
748,681	280,968
1,473,753	1,343,344
770,886	581,773

*American equivalent $0.50.
†74 lbs.

[1]See p. 110.
[2]For additional statistics, see p. 355.

CHINA

In the fiscal year ended June 30, 1914, China exported to the United States orange extract and glacéd kumquats and orange peel. Hongkong was the chief export point. Oranges, grapefruit, and limes are produced in large quantities.[1]

SYRIA

Ruppin gives some information concerning the importance of the exports of oranges, lemons, etc., from Syria.

According to the Turkish official statistics, the exports to foreign countries are given in Table LXX.

TABLE LXX

	Kilos	Value in Piasters
Via ports controlled by the Alexandrette customs office	2,551,625	2,227,516
Via Beyroot	83,460	93,571
Via other Syrian ports	28,055,310	23,280,704
Total	30,690,395	25,601,791

As per the English *Consular Reports,* the exports to foreign countries and to Turkey amounted to the figures given in Table LXXI.

TABLE LXXI

	1909	1910	1911	1912	1913
	Number of Cases				
From Jaffa	744,463	853,767	869,850	1,418,000	1,608,570
From Tripoli	134,000	218,000	135,000	140,000	.....
From Saida	188,000	125,000	70,000	79,600	.....
From Beyroot	3,200	1,200	4,800	1,860	.....
	Value in Francs				
From Jaffa	4,650,000	5,875,000	5,440,000	7,100,000	7,450,000
From Tripoli	600,000	900,000	600,000	600,000	.....
From Saida	800,000	500,000	300,000	300,000	.....
From Beyroot	10,000	5,000	15,000	6,000	.....

The Jaffa oranges, which can stand a longer journey, are mostly sent to Liverpool, in cases containing 144 and weighing about 35 kilos. During the shipping season (November to March) English ships go to Jaffa specially for the transport of oranges. It requires from seventeen to twenty days to land their cargo in Liverpool. The freight from Jaffa

[1]For additional statistics, see p. 355.

to Liverpool generally reaches 1.50 fr. per case. The other outlays of the producers, i.e., for picking and packing the fruit, etc., amount to 2 or 2½ fr. per case. The average price brought by the oranges in Liverpool being 7 to 8 fr. per box, there is a net profit of 3 to 4 fr. for the producer. Sometimes, higher prices are obtained, but it may likewise happen that, the Liverpool market being overstocked, the oranges have to be sold at considerable lower rates, or that they arrive in bad condition and not even cover the outlays. This risk is the most disagreeable feature of the otherwise remunerative orange growing. In addition to Liverpool, Jaffa oranges are exported to Egypt (in larger cases, inferior packing, and second-class fruit), Smyrna, Constantinople, and Odessa. Attempts have even been made to start an export to Australia and the United States.

The exports from Jaffa during the season 1913–14 were as follows:

Destination	Cases
Liverpool	887,481
Manchester	400
London	4,626
Other English ports	3,361
Marseilles	3,412
Hamburg	9,487
Trieste	58,492
Odessa	148,409
Egypt, the Red Sea, and Australia	149,846
Turkish ports	268,492
Roumania and Bulgaria	19,405
Total	1,553,861

In 1925, the Palestine Department of Agriculture and Forests estimated the orange acreage as 8,039 of which 7,105 lie in the Southern Circle, including the Jaffa and Gaza orange districts and 934 acres in the Northern Circle, including the Tulkarem and Haifa orange districts. The 1925 crop was estimated at 1,300,000 cases.[1]

The largest part of the Saida oranges remains in the country, for they cannot stand a long journey, owing to their being thin-skinned. In consequence, only small quantities go to Constantinople, Odessa, Roumania, and Liverpool, but fairly large quantities of lemons are exported. Tripoli exports oranges and lemons, about one-half to Odessa, a quarter to Constantinople, and the remaining quarter to Salonica, Alexandria, and Liverpool. The price in Tripoli was of late years about 8 to 10 fr. per case of 300 lemons and 4 to 5 fr. per box of 250 oranges.

[1] *Foreign Crops and Markets*, Vol. XI, No. 20, 1925.

(*La Parfumerie Moderne*)

MANUFACTURING PLANT AT NABEUL, TUNIS.

(*La Parfumerie Moderne*)

AN ARABIC STILL.

The Jaffa oranges are partly exported by dealers, who buy them before they are ripe, either at a lump sum for the whole crop of a plantation, or at a fixed price per case. As the oranges ripen in November, but may remain on the trees up to March or April without damage, the dealer has plenty of time for picking them. The Jewish orange growers

TABLE LXXII

ORANGES: PRODUCTION, PALESTINE, 1920–21 TO 1926–27*

SEASON (October—May)	QUANTITY (Cases)
1920–21	830,959
1921–22	1,234,251
1922–23	1,365,543
1923–24	1,589,331
1924–25	2,146,457
1925–26	1,511,000
1926–27 (estimate)	2,500,000

*Consul O. S. Heizer at Jerusalem, *Foreign Crops and Markets*, February 21, 1927.

in the neighborhood of Jaffa have formed two unions for the sale of their produce, and the German ones have followed their example; but so far it has been tried in vain to bring the Arabian owners of orange trees to act in a similar way.

The union decides when and where the oranges of its members are to be sent. Every member must put a certain mark on his cases, so that it is possible to give each a special account of sales, thus rewarding them for the good condition of the produce or making them responsible for bad quality.

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CHAPTER XVII

THE INDUSTRY IN AFRICA AND OCEANIA

AFRICA

Perhaps small amounts of citrus by-products are made in Africa. No record of them has been obtained. Rhodesia had over 150,000 trees planted with nearly 70,000 in bearing in 1919. Five thousand boxes of citrus fruit were exported to Europe and considerable quantities were supplied to local and Union markets. It was estimated that the 1920 crop was about 10,000 boxes.

ALGERIA

Of the principal fruits exported from Algeria during the five years 1909–13, lemons and oranges had an annual value of $172,000, and mandarins $449,000.

TABLE LXXIII

CITRUS FRUIT: AREA AND PRODUCTION OF ORANGES, MANDARINS, LEMONS, CITRONS, ETC., IN ALGERIA, 1921-22 AND 1922-23*

SEASON AND DISTRICT	ORANGES		MANDARINS		LEMONS, CITRONS, ETC.	
	Area (Acres)	Production (Pounds)	Area (Acres)	Production (Pounds)	Area (Acres)	Production (Pounds)
1921-22						
Alger	5,481	39,412,296	5,063	53,162,606	1,636	8,786,433
Oran	2,090	15,146,704	1,171	9,084,275	353	2,445,342
Constantine	1,737	9,116,021	902	8,973,163	902	8,127,258
Total	9,308	63,675,021	7,136	71,220,044	2,891	19,359,033
1922-23						
Alger	5,636	40,649,738	5,199	57,495,307	1,614	7,535,326
Oran	2,165	16,437,498	1,174	9,566,641	257	2,435,201
Constantine	2,454	18,046,856	1,443	14,318,436	1,045	10,689,885
Total	10,255	75,134,092	7,816	81,380,384	2,916	20,660,412

*Compiled from *Statistique Générale de l'Algérie*, 1922–23; *Foreign Crops and Markets*, February 21, 1927.

BRITISH SOUTH AFRICA

Within 8 or 10 years South Africa should have 7 or 8 million boxes of oranges available for export annually. While total exports of all citrus fruits amounted to only 530,000 boxes during the 1924 season, the rapid extension of acreage that has been taking place, particularly during 1924, will bring a great increase in exports as the new plantings come into

bearing. No reliable figures are available as to the present acreage of citrus fruits in South Africa, as figures for only a year ago are hopelessly out of date.

New developments are being undertaken chiefly as large scale projects with estates varying from 300 to 5,000 acres, the average being around 2,000. None of the large estates are yet in full bearing. One large estate in Northern Transvaal had 3,500 acres in oranges early in January with operations being carried on that would increase the area to 5,000 by June. In 7 to 8 years, the output from this one place alone should be over a million cases. This estate has gravity water sufficient to supply 5,500 acres. Another estate visited had 2,000 acres with another 1,000 to be planted.

TABLE LXIV

CITRUS FRUIT: SHIPMENTS FROM UNION OF SOUTH AFRICA, 1921–25*

(Boxes)

YEAR	LEMONS	ORANGES	TANGERINES	GRAPEFRUIT
1921	.....	217,746	22,236	2,820
1922	74	282,585	38,102	9,639
1923	43	356,087	41,103	13,474
1924	66	445,917	57,518	19,128
1925	4	676,368	67,500	25,287

*Unofficial trade source; *Foreign Crops and Markets*, February 21, 1927.

The scheme usually followed is to sell five acre plots or shares in a company, the money realized being used for further development. The company cares for the plots for five years, at the end of which time the buyer may either take over his plot or let the company run it, the latter being the usual case. Great numbers of plot holders are resident in England and India. The tracts of land are planted solidly—the five-acre demarcation being found only on the map—but with each plot containing 250 navels and 250 valencias. While this method is not a good way to set out a large place, as far as picking operators are concerned, it is of advantage, of course, to the settler who wishes to take over his plot.[1]

In 1914, $87,000 worth of oranges were exported.

MOROCCO

In Morocco orange blossoms are distilled by the natives in Marakesh and Fez.[2] About 80 per cent of the oranges cultivated in the neighborhood of Fez belong to the species of *Citrus bigarada*. In the district of Marakesh harvesting of these blossoms terminates in April while around

[1] *Foreign Crops and Markets*, Vol. X, No. 11, 1925.

[2] *Report of Schimmel & Co.* (April–October, 1916), p. 39.

Rabat it only reaches its height in that month and in Mekines it ends even later. In Fez the gathering of the blossoms lasts about twenty days. Marakesh and Fez are without doubt the most important centers of distillation. The natives possess only very primitive apparatus, and they produce the orange flower water but not the oil.

TUNIS

Lemons, mandarins, and oranges are cultivated here.

TABLE LXXV

CITRUS FRUIT: NUMBER OF TREES AND PRODUCTION, ORANGES AND CITRON, TUNIS, 1916–22*

YEAR	ORANGES		LEMONS, CITRONS, ETC.	
	Trees (Number)	Production (Pounds)	Trees (Number)	Production (Pounds)
1916	61,000	2,645,520	50,000	2,645,520
1917	61,000	3,086,440	50,000	2,425,060
1918	61,000	2,976,210	50,000	2,645,520
1919	63,000	3,196,670	51,000	2,755,750
1920	64,500	3,086,440	51,500	2,425,060
1921	66,000	3,350,992	52,000	2,865,980
1922	66,900	3,042,348	52,000	2,425,060

*Compiled from *Statistique Générale de la Tunisie*, 1922; *Foreign Crops and Markets*, February 21, 1927.

OCEANIA

AUSTRALIA

The production in the season 1912–13, of oranges was 1,402,000 bushels, valued at $1,953,000 and 375,000 bushels of lemons, valued at $430,000. Of these $129,000 worth was exported. Citrus fruits, how-

TABLE LXXVI

CITRUS FRUIT: PRODUCTION OF LEMONS AND ORANGES, AUSTRALIA AND NEW ZEALAND, 1919–20 TO 1925–26*

(Bushels)

YEAR	AUSTRALIA		NEW ZEALAND	
	Lemons	Oranges	Lemons	Oranges
1919–20	436,920	2,263,169	4,884	2,534
1920–21	464,572	2,582,867	7,500	2,339
1921–22	516,164	2,863,614	10,965	3,439
1922–23	463,951	2,898,759	10,998	3,738
1923–24	452,679	2,820,858	13,844	2,623
1924–25	.....	.....	20,785	3,540
1925–26	.....	.....	22,369	5,649

*Australia: *Production Bulletin*, 1919–20 to 1923–24. New Zealand: *Agricultural and Pastorial Production*, 1920–21 to 1925–26. *Foreign Crops and Markets*, February 21, 1927.

ever, were imported from Italy with an annual value of $141,000 during 1909–13. Citrus fruit production is rapidly increasing in Australia but is still on too small a scale to permit extensive by-product manufacture. The production is insufficient to meet the local demand and it is estimated that five years will be required until production is sufficient for export. The citrus territory is confined principally to the provinces of New South Wales and Victoria. Oranges and lemons have been grown there for sixty years. The varieties are: Thompson's improved navels, white selletas, Washington navels, seedlings, Valencias, and mandarins.

NEW ZEALAND

Citrus production is insufficient to meet local demand. Very few oranges are grown and but 300 acres of lemons, the latter near Auckland.

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APPENDIX

CITRUS FRUIT: PRODUCTION OF ORANGES AND LEMONS BY PRINCIPAL DISTRICTS, SPAIN, 1923–24 AND 1925–26*

(1,000 pounds)

DISTRICT	LEMONS		ORANGES	
	1923–24	1925–26	1923–24	1925–26
Levant†	31,668	52,089	1,519,091	2,268,750
Eastern Andalusia	22,623	45,292	98,951	128,397
Western Andalusia	1,092	1,661	132,953	144,666
Catalonia and Balearic Isles	4,051	2,774	41,773	26,730
Estremadura	1,151	1,357	6,328	8,864
Galicia	409	500	758	812
Cantabrica	205	194	220	220
Canary Islands	816	764	1,698	4,407
Total	62,039	104,631	1,801,844	2,582,920

*Armario, *Estadistico de Espana*, 1923–24; *Commercial Attaché* quoting *Consejo Agronomico*, 1925–26; *Foreign Crops and Markets*, February 21, 1927.

†Includes Valencia and Murcia.

CITRUS FRUIT: PRODUCTION IN FRANCE, 1914–24*

(1,000 pounds)

YEAR	LIMES (Citrons)	LEMONS (Cedrats)	MANDARINS	ORANGES
1914	390	21	354	1,014
1915	344	1,323	381	917
1916	621	1,543	395	1,213
1917	223	1,764	340	571
1918	240	183	562	1,499
1919	269	397	595	1,294
1920	467	1,014	728	1,246
1921	1,193	4,409	1,440	2,793
1922	1,442	5,511	1,616	2,619
1923	1,041	4,409	1,380	2,388
1924	937	2,646	392	2,634

*Compiled from *Statistique Agricole Annuelle*, France, 1914–24; *Foreign Crops and Markets*, February 21, 1927.

CITRUS OILS, ACID, AND CITRATE OF LIME EXPORTED FROM ITALY

(Average, in pounds)

Product	1909-13*	1923†	1924†	1925†
Citrus oils.....	1,406,076	2,034,890	2,301,988	2,380,463
Citric acid.....	103,616	2,932,779	4,256,201	6,121,733
Citrate of lime...	12,477,375	6,811,112	8,322,806	10,313,119

*Data compiled from *Movimento Commerciale del Regno d'Italia*, in *Foreign Crops and Markets*, Vol. XIV, No. 8, February 21, 1927.

†Data compiled from *Statistica del Commercio Speciale di Importagione e di Esportagione*, in *Foreign Crops and Markets*, Vol. XIV, No. 8, February 21, 1927.

IMPORTS OF LEMON OIL INTO THE UNITED STATES, 1898-1924

Year Ending June 30	Quantity (lb.)	Value
1898	160,264	$117,021.00
1899	237,302	185,728.00
1900	261,978	211,800.00
1901	268,341	231,040.78
1902	391,485	282,092.00
1903	361,210	233,487.00
1904	294,568	174,649.00
1905	310,056	175,852.00
1906	370,270	218,749.00
1907	487,717	423,133.00
1908	440,326	592,533.00
1909	405,695	358,197.00
1910	415,819	310,543.00
1911	430,768	323,552.00
1912	400,424	491,690.00
1913	410,003	794,215.00
1914	326,320	744,784.00
1915	557,347	621,592.00
1916	435,430	360,862.00
1917	557,288	459,179.00
1918	577,600	404,568.00
1919	345,799	327,370.00
1920	769,488	917,214.00
1921	543,189	559,282.00
1922	684,118	574,084.00
1923	416,232	258,102.00
1924	439,181	292,981.00

IMPORTS OF NEROLI OR ORANGE FLOWER OIL INTO THE UNITED STATES, 1898–1923

Year	Quantity (lb.)	Value
1898	1,535	$ 18,511.00
1899	1,911	22,673.00
1900	2,250	26,893.00
1901	4,319	41,922.00
1902	7,761	64,963.00
1903	5,853	58,067.00
1904	4,446	39,423.00
1905	4,995	28,957.00
1906	11,737	95,759.00
1907	8,669	181,304.00
1908	11,271	118,301.00
1909	23,184	170,342.00
1910	26,053	70,433.00
1911	16,208	49,306.00
1912	17,437	71,054.00
1913	38,365	171,932.00
1914	15,928	73,265.00
1915	13,251	31,478.00
1916	34,447	66,768.00
1917	23,639	66,394.00
1918	32,687	84,880.00
1919	10,595	52,850.00
1920	49,835	214,919.00
1921	22,780	95,227.00
1922	51,989	61,840.00
1923	1,590	67,978.00

IMPORTS OF ORANGE OIL INTO THE UNITED STATES, 1898–1924

Year	Quantity (lb.)	Value
1898	33,732	$ 45,287.00
1899	52,378	68,322.00
1900	57,069	95,405.00
1901	72,218	109,832.00
1902	79,160	104,159.00
1903	77,138	107,808.00
1904	74,816	109,478.00
1905	92,077	143,555.00
1906	74,535	122,634.00
1907	112,834	199,027.00
1908	71,224	165,982.00
1909	87,591	151,860.00
1910	46,814	65,488.00
1911	73,804	100,115.00
1912	97,065	168,831.00
1913	79,797	155,299.00
1914	104,491	222,118.00
1915	97,014	140,246.00
1916	97,539	134,025.00
1917	170,722	322,373.00
1918	196,846	330,506.00
1919	126,532	246,202.00
1920	282,349	953,514.00
1921	155,765	543,088.00
1922	210,034	558,374.00
1923	221,642	443,093.00
1924	202,595	491,843.00

IMPORTS OF CITRIC ACID INTO THE UNITED STATES, 1898–1924

Year	Quantity (lb.)	Value	Average Price per Lb.
1898	4,323	$ 1,108.55	.....
1899	65,190	16,659.00	.....
1900	60,354	14,213.00	.....
1901	76,805	23,038.00	.....
1902	74,712	21,084.68	.....
1903	12,338	3,544.00	.....
1904	5,546	1,461.00	.....
1905	2,778	728.00	.....
1906	65,747	21,067.00	.....
1907	149,208	57,061.00	.....
1908	171,796	62,804.00	.....
1909	243,010	74,209.00	.....
1910	142,001	40,967.00	.....
1911	97,847	28,717.00	$ .293
1912	67,332	20,275.00	.301
1913	8,677	2,916.00	.336
1914	652,210	304,347.00	.313
1915	722,434	447,131.00	.619
1916	171,877	107,603.00	.626
1917	157,528	91,463.00	.581
1918	196,590	126,066.00	.641
1919	680,146	632,364.00	.....
1920	1,621,577	1,426,195.00	.....
1921	770,331	632,780.00	.....
1922	1,624,892	609,198.00	.....
1923	820,370	250,845.00	.....
1924	744,624	206,107.00	.....

IMPORTS OF CITRATE OF LIME INTO THE UNITED STATES, 1898–1924

Year	Quantity (lb.)	Value
1898	1,026,467	$ 84,789.00
1899	1,577,804	157,432.00
1900	1,944,863	204,243.00
1901	2,416,088	299,583.00
1902	3,066,904	293,293.00
1903	2,657,110	240,466.00
1904	2,926,529	274,130.00
1905	3,444,344	355,728.00
1906	3,903,234	534,977.00
1907	3,872,924	726,626.00
1908	3,853,105	580,293.00
1909	3,917,274	489,031.00
1910	4,114,256	568,175.00
1911	5,219,544	712,004.00
1912	5,903,501	791,416.00
1913	5,526,954	756,309.00
1914	3,119,924	496,517.00
1915	6,242,244	1,109,629.00
1916	8,128,364	1,763,652.00
1917	6,361,458	1,554,577.00
1918	4,013,606	814,073.00
1919	2,773,095	1,136,057.00
1920	10,431,314	2,908,023.00
1921	5,060,407	1,104,576.00
1922	8,983,134	1,194,964.00
1923	1,672,604	200,143.00
1924	2,505,444	256,807.00

IMPORTS OF CITRATE OF LIME INTO THE UNITED STATES, BY COUNTRIES, FOR FISCAL YEARS 1910–17 AND CALENDAR YEARS 1918–20 (IN POUNDS)*

Countries	Years Ending June 30								Calendar Years		
	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
France	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	66,460
Italy	3,354,404	4,499,927	4,764,601	5,100,658	2,607,660	6,194,743	8,672,887	4,926,633	2,775,439	3,324,902	11,901,667
United Kingdom	.....	.....	245,075	.....	.....	1,549	.....	.....	.....	2,352	3,727
Mexico	76,182	55,923	103,325	55,261	6,995	.....	16,954	10,856	42,307	90,673	11,692
West Indies	393,145	662,790	570,251	290,342	482,610	268,033	167,377	210,148	42,066	366,567	449,495
British Guiana	1,283	1,904	.....	.....	.....	.....	1,960	.....	.....	.....	.....
Canada	.....	.....	.....	.....	.....	.....	.....	.....	101,833	.....	.....
Panama	.....	.....	.....	.....	.....	.....	.....	.....	.....	7,200	57,155
Total	3,825,014	5,220,544	5,683,252	5,446,261	3,097,265	6,464,325	8,859,178	5,147,637	2,961,645	3,791,694	12,490,196

* Statement prepared by Foreign Markets Service, Bureau of Markets.

IMPORTS OF LEMON OIL INTO THE UNITED STATES, BY COUNTRIES, FOR FISCAL YEARS 1910–17 AND CALENDAR YEARS 1918–20 (IN POUNDS)*

Countries	Years Ending June 30								Calendar Years		
	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
Austria Hungary	.....	.....	.....	.....	81	.....	.....	.....	.....	.....	.....
Belgium	.....	.....	.....	.....	417	.....	.....	.....	.....	.....	.....
Denmark	.....	.....	.....	.....	.....	57	.....	.....	.....	.....	.....
France	610	1,131	4,888	395	1,690	75	.....	7	15,154	16,979	44,191
Germany	1,784	1,334	1,943	9,819	13,458	707	40	.....	.....	.....	35
Italy	412,630	426,117	346,083	363,172	362,839	575,657	543,125	443,334	565,662	581,788	685,842
Netherlands	.....	.....	.....	86	.....	.....	.....	63	.....	5	20
Spain	.....	.....	.....	1,675	.....	.....	.....	1,237	.....	8,449	.....
Switzerland	55	.....	110	694	68	.....	205	5	.....	.....	.....
Turkey in Europe	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2,220
United Kingdom	.....	1,000	1,015	3,824	7,156	646	.....	1,000	76	5	17,907
Canada	25	876	.....	619	250	37	470	385	191	55	250
Mexico	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....
British West Indies	397	.....	.....	808	.....	416	.....	175	5,326	.....	.....
Cuba	.....	.....	.....	.....	.....	.....	.....	6	.....	.....	250
DominicanRepublic	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	70
British India	.....	.....	3,135	.....	.....	.....	.....	3,465	.....	.....	.....
China	.....	.....	.....	.....	.....	.....	2	1	.....	.....	.....
Hongkong	.....	.....	.....	.....	.....	.....	.....	7	.....	.....	.....
Japan	.....	.....	.....	.....	.....	.....	15	50	1,560	5	.....
Total	415,501	430,458	357,174	381,093	385,959	577,595	543,857	449,735	587,969	607,286	750,785

* Statement prepared by Foreign Markets Service, Bureau of Markets.

IMPORTS OF LEMON, LIME, AND SOUR ORANGE JUICE INTO THE UNITED STATES, 1898-1924

Year	Quantity (lb.)	Value
1898	.....	$ 73,640.00
1899	.....	97,975.42
1900	.....	70,625.00
1901	.....	122,469.35
1902	.....	92,554.20
1903	.....	105,432.00
1904	.....	65,883,67
1905	.....	74,057.11
1906	.....	94,471.39
1907	.....	98,658.00
1908	.....	102,746.00
1909	.....	81,386.00
1910	.....	65,319.00
1911	.....	88,683.00
1912	.....	117,353.00
1913	.....	116,370.25
1914	.....	110,860.00
1915	.....	139,605.00
1916	.....	152,575.00
1917	.....	180,088.00
1918	.....	114,404.00
1919	1,933,465	277,031.00
1920	3,254,633	515,004.00
1921	1,009,300	164,827.00
1922	1,083,583	169,216.00
1923	2,443,402	199,958.00
1924	4,158,396	565,738.00

TOTAL CARS AND BOXES OF ORANGES AND LEMONS SHIPPED FROM CALIFORNIA

YEAR ENDING OCTOBER 31	ORANGES		LEMONS		TOTAL	
	Cars	Boxes	Cars	Boxes	Cars	Boxes
1903	21,080	8,094,720	2,649	826,500	23,729	8,921,220
1904	26,684	10,246,656	2,782	868,000	29,466	11,114,656
1905	27,342	10,225,908	4,274	1,335,500	31,616	11,559,542
1906	23,739	8,973,342	3,789	1,182,200	27,528	10,155,542
1907	26,319	10,290,729	3,507	1,097,300	29,826	11,388,029
1908	27,688	10,742,944	4,959	1,585,000	32,647	12,327,944
1909	34,396	13,441,016	6,196	2,019,896	40,572	15,460,912
1910	28,252	11,187,792	4,891	1,627,480	33,143	12,815,272
1911	39,508	15,645,168	6,891	2,315,376	46,399	17,960,544
1912	34,547	13,680,612	6,133	2,146,550	40,680	15,827,162
1913	16,027	6,346,692	2,304	866,304	18,331	7,212,996
1914	45,306	17,986,482	3,312	1,174,242	48,618	19,160,724
1915	39,742	15,857,856	7,068	2,601,024	46,810	18,458,880
1916	37,897	15,490,399	7,186	2,712,715	45,083	18,203,114

TOTAL CARS OF ORANGES AND LEMONS SHIPPED FROM NORTHERN CALIFORNIA

Year Ending October 31	Cars of Lemons	Cars of Oranges	Total Cars for Northern California	Total Cars for State
1903	.....	.....	,304	23,729
1904	.....	.....	1,567	29,466
1905	.....	.....	1,734	31,616
1906	.....	.....	1,564	27,528
1907	.....	.....	2,333	29,826
1908	.....	.....	3,150	32,647
1909	.....	.....	2,501	40,572
1910	2,921	109	3,030	33,143
1911	2,687	127	2,814	46,399
1912	4,220	172	4,392	40,680
1913	2,453	112	2,565	18,331
1914	6,282	78	6,360	48,338
1915	6,427	225	6,652	46,812
1916	6,026	170	6,196	45,083
1917	5,889	167	6,056	54,506
1918	2,773	140	2,913	23,456
1919	3,993	266	4,259	49,436
1920	5,654	312	5,966	44,724
1921	6,981	221	7,202	60,116
1922	5,487	119	5,606	39,499
1923	7,782	262	8,048	59,707
1924	7,662	239	7,901	60,735

TOTAL CARS OF ORANGES AND LEMONS SHIPPED FROM SOUTHERN CALIFORNIA

Year Ending October 31	Cars of Lemons	Cars of Oranges	Total Cars from Southern California
1887	12	2,200	2,212
1888	20	2,500	2,520
1889	26	2,782	2,808
1890	34	3,476	3,510
1891	40	4,016	4,056
1892	52	4,400	4,452
1893	65	5,871	5,936
1894	145	5,726	5,871
1895	335	4,687	5,022
1896	565	7,010	7,575
1897	1,378	5,972	7,350
1898	1,166	13,987	15,153
1899	903	9,448	10,351
1900	1,447	16,362	17,809
1901	2,924	21,173	24,097
1902	2,816	17,571	20,387
1903	2,649	19,776	22,425
1904	2,782	25,117	27,889
1905	4,274	25,608	29,882
1906	3,789	22,175	25,964
1907	3,507	23,986	27,493
1908	4,959	24,538	29,497
1909	6,196	31,875	38,071
1910	4,782	25,331	30,113
1911	6,764	36,821	43,585
1912	5,961	30,327	36,288
1913	2,192	13,574	15,768
1914	2,954	39,024	41,978
1915	6,843	33,317	40,160
1916	7,016	31,871	38,887
1917	7,748	40,702	48,450
1918	6,197	14,346	20,543
1919	9,741	35,436	45,177
1920	8,733	30,025	38,758
1921	11,584	41,330	52,914
1922	9,807	24,086	33,893
1923	8,479	43,180	51,659
1924	12,861	39,973	52,834

LEMONS: *EXPORTS FROM THE UNITED STATES, BY COUNTRIES, YEAR ENDING JUNE 30, 1913–23 AND NINE MONTHS (JULY, 1923–MARCH, 1924)†
(In boxes. 1 box = 84 lbs.)

Year Ending June 30	Canada	Australia	Russia in Asia	New Zealand	China	Philippine Islands	Other Countries	Total
1913	74,310	50	.....	150	1,897	2,069	3,473	81,949
1914	64,334	.....	3	.....	2,107	725	2,906	70,075
1915	100,075	5,375	2,997	2,370	2,966	3,479	5,652	122,914
1916	135,183	9,799	7,434	6,370	4,967	3,517	7,800	175,070
1917	143,709	5,800	656	8,482	6,216	2,993	7,082	174,938
1918	122,153	.....	100	3,683	4,522	2,892	4,713	138,063
1919	279,836	.....	30	5,291	9,594	3,542	6,058	304,351
1920	239,335	5,010	31	10,111	10,265	4,200	7,567	276,519
1921	269,397	1,250	65	13,030	12,770	5,702	8,627	310,841
1922	198,428	.....	11	10,155	10,954	5,860	8,407	233,815
1923	126,899	715	1	8,457	9,126	5,076	8,573	158,847
July, 1923–March, 1924.	109,994	1,036	1	9,060	6,878	3,387	10,484	140,840

* Included in "All other, green, ripe or dried," prior to 1913.

† Compiled from *Commerce and Navigation of the United States, 1913–1918*, and *Monthly Summaries of Foreign Commerce of the United States.*

PRODUCTION OF ORANGES, GRAPEFRUIT, AND LEMONS, BY STATES, FOR VARIOUS PERIODS*

(Thousand boxes, i. e., 000 omitted)

STATES	1889†	1899†	1909†	1919†	1920‡	1921‡	1922‡	1923‡	1924‡	1925‡
ORANGES										
Florida	3,147	273	4,888	‡7,000	8,100	8,700	11,200	14,000	14,100	14,100
California	1,245	5,882	17,440	‡16,192	22,030	13,726	21,091	23,095	18,100	20,400
Arizona	.....	11	32	80	60	80	81	86	86	100
Alabama	.....	0	1	41	165	165	350	450	0	150
Louisiana	.....	1	150	37	42	50	60	75	75	100
Mississippi	.....	.....	4	32	25	30	45	55	0	30
Texas	.....	.....	11	9	.....	.....	4	6	12	16
GRAPEFRUIT										
Florida	10	12	1,062	‡5,500	5,100	7,000	8,200	9,500	10,500	8,200
California	.....	18	123	‡263	304	360	394	363	387	400
Mississippi	.....	.....	1	.....	1	1	1	1	0	1
Arizona	.....	1	1	30	34	35	44	44	44	44
Alabama	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Louisiana	.....	.....	2	.....	.....	.....	.....	.....	.....	.....
Texas	.....	.....	.....	.....	.....	.....	35	65	211	299
LEMONS										
Florida	253	2	12	32	.....	.....	.....	.....	.....	.....
California	306	874	2,756	‡3,949	5,255	4,172	3,492	6,840	5,125	6,000

*Where leaders occur data were not available.

†Data from census reports.

‡Compiled from records of Division of Crop and Livestock Estimates for season beginning in California November 1, all other states September 1. *United States Department of Agriculture Bulletin No. 1435* (1926).

LEMONS: *IMPORTS INTO THE UNITED STATES, BY COUNTRIES, YEAR ENDING JUNE 30, 1910–13, 1922, 1923, AND NINE MONTHS (JULY, 1923—MARCH, 1924)†

(In boxes. 1 box = 84 lbs.)

Year Ending June 30	Italy	Cuba	Other Countries	Total
1910	1,891,453	358	15,508	1,907,319
1911	1,591,664	265	14,844	1,606,773
1912	1,729,466	203	4,133	1,733,802
1913	1,778,466	1,346	22,764	1,802,576
1922‡	789,729	.....	5,136	794,865
1923	1,441,603	188	20,333	1,462,124
July, 1923–March, 1924	611,286	.....	6,546	617,832

*Reported in value only, 1914–December, 1921.

†Compiled from *Commerce and Navigation of the United States, 1910–13*, and *Monthly Summaries of Foreign Commerce of the United States*.

‡January–June, 1922.

LEMONS: IMPORTS INTO THE UNITED STATES BY MONTHS, NOVEMBER, 1922—APRIL, 1924*
(In boxes. 1 box=84 lbs.)

Month	1921–22	1922–23	1923–24
July	29	204,930	286,704
August	.....	68,452	87,522
September	.....	32,614	103,723
October	.....	51,336	37,149
November	29,581	89,384	34,874
December	12,718	79,914	18,636
January	27,014	89,397	10,818
February	47,756	35,173	24,884
March	125,282	194,882	18,300
April	105,720	137,283	.....
May	214,616	166,099	.....
June	262,571	312,695	.....
Total for year ending June 30	.....	1,462,159	(9 mo.) 622,610

*Compiled from *Monthly Summaries of the Bureau of Foreign and Domestic Commerce.*

MONTHLY AVERAGE WHOLESALE PRICES OF CALIFORNIAN AND SICILIAN LEMONS IN NEW YORK, JANUARY, 1922, TO APRIL, 1924*

(Expressed as flat averages, in dollars, of range of quotations per box of 300 to 360 lemons of first quality)

Month	1922		1923		1924	
	Californian	Sicilian	Californian	Sicilian	Californian	Sicilian
January	4.54	....	5.72	3.65	3.58	3.22
February	6.15	4.78	5.81	4.44	3.40	2.84
March	5.07	3.40	4.98	3.69	3.56	3.42
April	4.61	3.58	5.03	3.05	3.71	3.53
May	5.58	4.46	6.09	3.80	.....	.....
June	6.28	5.56	8.69	5.98	.....	.....
July	5.06	4.38	6.60	5.65	.....	.....
August	5.44	4.24	8.66	6.23	.....	.....
September	8.54	6.53	7.18	5.33	.....	.....
October	10.78	7.10	5.00	3.02	.....	.....
November	10.22	6.42	3.76	3.06	.....	.....
December	7.04	4.83	3.73	2.91	.....	.....

**New York Packer*, weekly.

EXPORTS OF CITRATE OF LIME AND CITRIC ACID, FROM ITALY BY COUNTRIES, 1913*

EXPORTED TO	CITRATE OF LIME		CITRIC ACID	
	Quantity (lb.)	Value	Quantity (lb.)	Value
Austria	539,466	$ 78,397	1,102	$ 434
France	2,103,639	305,707	29,321	11,551
Germany	1,070,554	155,577	75,177	29,616
Great Britain	1,946,221	282,831	53,572	21,105
Netherlands	184,966	26,880	160,274	63,140
United States	2,561,083	372,185	8,818	3,474
All Others	.....	.....	157,849	62,184
Total	8,405,919	1,221,577	486,114	191,504

*From *Movimento Commerciale del regno d'Italia.*

EXPORTS OF CITRATE OF LIME AND CITRIC ACID FROM ITALY, 1909–17*

YEAR	CITRATE OF LIME		CITRIC ACID	
	Quantity (lb.)	Value	Quantity (lb.)	Value
1909	5,248,932	$ 735,222	3,527	$ 714
1910	13,834,967	1,853,092	1,764	548
1911	17,964,844	2,406,259	35,935	7,156
1912	16,931,989	2,356,854	5,071	1,642
1913	8,405,919	1,221,577	486,114	191,504
1914	12,539,324	2,063,762	1,320,114	635,626
1915	14,779,638	2,458,357	1,665,134	1,093,297
1916	16,047,063	3,441,829	2,302,925	2,016,078
1917	12,869,793	2,760,356	1,834,227	1,605,760

*From *Movimento Commerciale del regno d'Italia.*

EXPORTS OF CITRATE OF LIME AND CITRIC ACID FROM ITALY, BY COUNTRIES, 1917*

EXPORTED TO	CITRATE OF LIME		CITRIC ACID	
	Quantity (lb.)	Value	Quantity (lb.)	Value
France	1,149,258	.....	454,809	.....
Great Britain	4,209,463	.....	691,803	.....
United States	7,511,072	.....	303,573	.....
Servia	.....	.....	10,362	.....
Switzerland	.....	.....	6,614	.....
All Others	.....	.....	367,066	.....
Total	12,869,793	$2,760,356	1,834,227	$1,605,760

*From *Statistica del Commercio Speciale di Importazione e di Esportazione.*

EXPORTS OF ESSENTIAL OIL OF LEMON FROM ITALY, 1909–17*

Year	Quantity (lb.)	Value	Year	Quantity (lb.)	Value
1909	803,901	$ 633,392	1914	1,329,369	$2,094,815
1910	937,123	738,357	1915	1,640,247	1,794,926
1911	1,155,164	1,112,407	1916	1,445,164	1,581,447
1912	1,141,092	1,498,440	1917	1,151,873	957,978
1913	1,005,966	1,320,997			

*From *Movimento Commerciale del regno d'Italia.*

RATES OF IMPORT DUTIES ON CITRUS PRODUCTS IN THE UNITED STATES, 1883-1925

Year	Citrate of Lime	Citric Acid	Lemon Oil	Lemon Juice, Lime Juice, and Sour Orange Juice
1883..	Free	10 cents per lb.	25%	Free (lemon juice, lime juice)
1890..	Free	10 cents per lb.	Free	Free
1894..	Free	25%	Free	Free
1897..	Free	7 cents per lb.	Free	Free
1909..	Free	7 cents per lb.	Free	Free (not more than 2 per cent alcohol)
1913..	1 cent per lb.	5 cents per lb.	10%	Free (not more than 2 per cent alcohol)
1922..	.....	17 cents per lb.	.....	.....

RATES OF IMPORT DUTIES ON CITRATE OF LIME IN PRINCIPAL COUNTRIES*

Countries	Tariff No.	Foreign Rate	United States Equivalents† (dollars per pound)
United States	41		$0.01
United Kingdom		Free	Free
France	263	Free	Free
Germany‡	317	Free	Free
Russia§	112 (9)	5 roubles + 10% per pood gross	0.0862
Italy:			
General tariff	80	10 lire per quintal	0.0087
Canada:			
British preferential	711	20% ad valorem	20% ad valorem
Intermediate	711	35% ad valorem	25% ad valorem
General‖	711	35% ad valorem	25% ad valorem
Australia:§			
British preferential	281	Free	Free
General Tariff‖**	281	5% ad valorem	5% ad valorem
Japan§	229	20% ad valorem	20% ad valorem

*Compiled from official texts on file in Bureau of Foreign and Domestic Commerce, Department of Commerce, and corrected to January 1, 1919.

†Conversions into United States currency are based on par value.

‡Metalloids, acids, salts, and combinations of metalloids one with another or with metals, not specified above or elsewhere.

§Chemicals, N. O. S.

‖The general rate is applied to the United States.

**Articles, N. O. S.

RATES OF IMPORT DUTIES ON CITRIC ACID IN THE PRINCIPAL COUNTRIES

Countries	Tariff No.	Foreign Rate	United States Equivalents† (dollars per lb.)
United States	1	.....	$0.05
United Kingdom	...	Free	Free
France:‡			
General tariff§	238	75 francs per 100 kilos	0.0657
Minimum tariff	238	50 francs per 100 kilos	0.0438
Germany:			
General rate	279	8 marks per 100 kilos	0.0086
Conventional rate‖	279	Free	Free
Austria Hungary:			
General tariff	600	15 per cent ad valorem	15%
Conventional tariff	600	15 per cent ad valorem	15%
Italy:			
General rate	37f	50 lire per quintal	0.0438
Japan	160	27.50 yen per 100 kin	0.1031
Canada:			
British preferential tariff	216	20 per cent	20%
Intermediate tariff	216	27½ per cent	27½%
General tariff§	216	30 per cent	30%
Mexico	515	5 centavos per kilo	0.011
Brazil	178	700 reis per kilo	0.081
Chile	1,360	50 centavos per kilo	0.0828
Argentine	39	7.8 centavos per kilo	0.0341
Australia:			
British preferential tariff	279	Free	Free
General§	279	5 per cent ad valorem	5%

*Compiled from official texts on file in the Bureau of Foreign and Domestic Commerce, Department of Commerce, and corrected to January 1, 1919.

†Conversions into United States currency are based on par value.

‡Citric acid, crystallized.

§General tariff applies to the United States.

‖Conventional tariff applies to the United States.

WHOLESALE PRICES OF CITRIC ACID (CRYSTALS) AT NEW YORK, 1911–19*
(Cents per pound, spot)

Month	1911	1912	1913	1914	1915	1916	1917	1918	1919
January	38½-39	38½-39	38½-39	51-51½	55-55½	59-59½	65-65½	72-72½	125-125½
April...	38½-39	38½-39	40-41	51-51½	55-55½	64-64½	72-72½	82	125-125½
July...	38½-39	38½-39	44-44½	53-53½	55-55½	55-55½	72-72½	82-88	98
October	38½-39	38½-39	55-55½	90-95	55-55½	55-55½	72-72½	82-82½	93- 94

*From *Oil, Paint and Drug Reporter.*

COMPARISON OF WHOLESALE PRICES OF CITRIC ACID IN ITALY, AUSTRALIA, AND THE UNITED STATES, BY QUARTERS, 1913–18*

YEARS AND QUARTERS	ACTUAL PRICE					RELATIVE PRICE		
	Italy	Australia			United States	Italy	Australia	United States
Market	Genoa	Melbourne			New York			
Unit	100 kg.	Pound			Pound			
	Lire	£	*s.*	*d.*	*Dollars*			
Base price†	572.25	0	2	3.50	0.5070	100	100	100
1913 First	425.00	0	1	7.08	.3980	74	69	79
Second	464.17	0	1	9.00	.4080	81	76	80
Third	476.25	0	1	10.67	.4500	86	82	89
Fourth	605.00	0	2	3.25	.5330	103	99	105
1914 First	598.33	0	2	5.08	.5100	105	106	101
Second	588.33	0	2	7.00	.5350	103	113	106
Third	680.00	0	2	11.50	.5850	119	129	115
Fourth	715.00	0	3	10.50	.7430	125	169	147
1915 First	681.67	0	3	8.50	.5690	119	162	112
Second	778.33	0	3	4.50	.5890	136	147	116
Third	1,034.17	0	3	3.00	.6225	181	142	123
Fourth	800.00	0	3	4.50	.6080	140	147	120
1916 First	916.67	0	3	3.75	.6730	160	145	133
Second	1,086.67	0	3	5.25	.6925	190	150	137
Third	1,065.83	0	3	6.50	.7175	186	155	142
Fourth	941.67	0	3	4.50	.7125	165	147	141
1917 First	‡	0	3	4.50	.6980	‡	147	38
Second	‡	0	3	7.33	.7500	‡	158	148
Third	‡	0	3	11.00	.7650	‡	171	151
Fourth	‡	0	4	1.00	.7650	‡	178	151
1918 First	1,383.33	0	4	2.00	.7940	242	182	157
Second	1,400.00	0	4	2.50	.8475	245	184	167
Third	1,385.00	0	4	6.75	.8525	242	199	168
Fourth	.....	0	4	5.25	1.0470	.....	194	207

*Source: *International Price Comparisons*, Department of Commerce, Washington, 1919.
†Average actual prices from July, 1913, to June, 1914.
‡Statistics not available.

OIL OF ORANGE, OIL OF BERGAMOT, OIL OF LEMON—EXPORTS OF CITRUS OILS FROM ITALY, 1912–19

YEAR	OIL OF BERGAMOT		OIL OF LEMON		OIL OF ORANGE		OIL OF MANDARIN	
	Quantity (lb.)	Value	Quantity (lb.)	Value	Quantity (lb.)	Value	Quantity (lb.)	Value
1912	157,283	$ 853,690	1,141,092	$1,498,440	118,615	$218,064	2,088	$10,052
1913	139,095	803,679	1,007,293	3,086,393	106,048	278,516	2,013	10,573
1914	136,149	476,764	1,329,369	2,094,815	94,441	157,087	2,163	7,195
1915	232,702	651,895	1,640,247	1,794,926	155,803	218,235	2,661	10,716
1916	346,486	1,304,312	1,445,164	1,201,899	211,767	500,553	4,054	25,199
1917	294,973	1,678,508	1,151,873	1,109,238	159,496	488,704	5,401	33,099
1918	301,737	1,981,150	1,283,897	1,798,365	108,266	379,121	4,766	33,382
1919	*428,839	2,815,677	*1,670,511	2,339,898	*229,087	802,208	*8,909	62,393

*Preliminary figure from monthly report for December, 1919.

EXPORTS OF ITALIAN ESSENTIAL CITRUS OILS, BY PRINCIPAL COUNTRIES, 1916

COUNTRIES	OIL OF ORANGE		OIL OF LEMON		OIL OF BERGAMOT	
	Quantity (lb.)	Value	Quantity (lb.)	Value	Quantity (lb.)	Value
France	33,065	$ 78,155	86,356	$ 71,819	10,246	$385,688
Great Britain	34,226	80,901	355,293	295,487	6,932	260,921
Russia	12,419	29,354	44,921	37,259	2,867	107,945
Switzerland	41,799	98,801	123,916	103,057	3,770	141,921
Australia	2,767	6,540	51,182	42,567	154	5,950
United States	66,877	158,076	637,132	29,883	4,872	183,416
All Others	20,611	48,728	14,636	121,726	5,808	218,471
Total	211,767	$500,553	144,516	$1,201,899	34,649	$1,304,312

CITRIC ACID MANUFACTURED IN THE UNITED STATES, 1904–17

Year	Quantity (lb.)	Year	Quantity (lb.)
1904	2,265,631	1915	3,417,795
1909	2,102,256	1916	4,188,538
1914	2,729,943	1917	4,082,897

BERGAMOT, SYNTHETIC—PRICES PER POUND*

July, 1915	$2.50–$2.75	April, 1918	$3.50–$4.00
October, 1915	2.50– 2.75	July, 1918	3.75– 3.89
January, 1916	2.50– 2.75	October, 1918	4.00– 4.25
April, 1916	2.90– 3.00	January, 1919	4.00– 4.25
July, 1916	2.90– 3.00	April, 1919	4.00– 4.25
October, 1916	2.90– 3.00	July, 1919	4.00– 4.25
January, 1917	2.75– 3.00	October, 1919	4.00– 4.25
April, 1917	2.75– 3.00	January, 1920	4.00– 4.25
July, 1917	3.00– 3.20	April, 1920	4.00– 4.25
October, 1917	3.00– 3.50	July, 1920	4.00– 4.25
January, 1918	3.50– 4.00	October, 1920	4.00– 4.25

*From *Oil, Paint, and Drug Reporter.*

OIL OF LIME, EXPRESSED—PRICES PER POUND*

August, 1914	$3.25–$3.50	January, 1918	$5.75–$6.00
January, 1915	3.00– 3.10	April, 1918	5.50– 5.75
April, 1915	2.65– 2.75	July, 1918	5.25– 5.50
July, 1915	2.75– 2.85	October, 1918	5.00– 5.25
October, 1915	2.75– 3.00	January, 1919	4.90– 5.00
January, 1916	2.75– 3.00	April, 1919	4.50– 4.75
April, 1916	2.75– 3.00	July, 1919	3.95– 4.00
July, 1916	3.15– 3.25	October, 1919	3.75– 3.85
October, 1916	3.15– 3.25	January, 1920	3.50– 3.75
January, 1917	3.50– 4.00	April, 1920	5.50– 5.75
April, 1917	5.00– 5.25	July, 1920	†
July, 1917	5.50– 6.00	October, 1920	5.50– 5.60
October, 1917	6.50		

*From *Oil, Paint, and Drug Reporter.*
†Nominal

OIL OF LIME, DISTILLED—PRICES PER POUND*

August, 1914	$0.75–$0.80	January, 1918	$2.25–$2.35
January, 1915	1.35– 1.40	April, 1918	$2.00– 2.25
April, 1915	1.10– 1.15	July, 1918	1.90– 2.00
July, 1915	1.60	October, 1918	1.85– 1.90
October, 1915	2.35	January, 1919	1.65– 1.75
January, 1916	2.25– 2.35	April, 1919	1.50– 1.60
April, 1916	2.25– 2.50	July, 1919	1.15– 1.25
July, 1916	2.75– 3.00	October, 1919	1.10– 1.15
October, 1916	2.75– 3.00	January, 1920	1.00– 1.10
January, 1917	2.75– 3.00	April, 1920	1.00– 1.25
April, 1917	2.50– 2.75	July, 1920	2.25– 2.40
July, 1917	2.75– 2.85	October, 1920	1.75– 1.85
October, 1917	2.75– 2.85		

*From *Oil, Paint, and Drug Reporter.*

NEROLI-BIGARADE—PRICES PER POUND*

August, 1914	$40.00–$50.00
January, 1915	55.00
April, 1915	35.00– 40.00
July, 1915	35.00– 40.00
October, 1915	35.00– 50.00
January, 1916	35.00– 50.00
April, 1916	35.00– 50.00
July, 1916	35.00– 50.00
October, 1916	35.00– 50.00
January, 1917	35.00– 50.00
April, 1917	35.00– 50.00
July, 1917	40.00– 50.00
October, 1917	75.00– 78.00
January, 1918	$70.00–$80.00
April, 1918	70.00– 80.00
July, 1918	70.00– 80.00
October, 1918	80.00–100.00
January, 1919	80.00–120.00
April, 1919	130.00
July, 1919	120.00
October, 1919	120.00
January, 1920	120.00
April, 1920	120.00
July, 1920	120.00
October, 1920	†

*From *Oil, Paint, and Drug Reporter.*
†Nominal.

OIL OF ORANGE, SWEET ITALIAN—PRICES PER POUND*

Quarters, 1913:†	
First	$2.85
Second	3.11
Third	3.71
Fourth	3.56
Quarters, 1914:†	
First	2.95
Second	2.45
Third	2.61
Fourth	1.88
Quarters, 1915:†	
First	1.56
Second	1.61
Third	1.85
Fourth	1.76
Quarters, 1916:†	
First	1.86
Second	2.53
Third	2.83
Fourth	2.86
Quarters, 1917:†	
First	$3.00
Second	2.86
Third	3.03
Fourth	2.80
Quarters, 1918:†	
First	2.55
Second	2.56
Third	2.58
Fourth	3.00
Quarters, 1919:‡	
First	2.90
Second	3.10
Third	2.90
Fourth	3.25
Quarters, 1920:‡	
First	5.25
Second	9.00
Third	10.75
Fourth	6.25

*From *War Industries Board Bulletin No. 50* and *Oil, Paint, and Drug Reporter.*
†Quarterly prices, or average of monthly prices from *Oil, Paint, and Drug Reporter.*
‡Low, first Monday in each month, from *Oil, Paint, and Drug Reporter.*

ORANGE, BITTER—PRICES PER POUND*

April, 1915	$1.75–$2.00
July, 1915	2.00– 2.10
October, 1915	2.00– 2.10
January, 1916	2.00– 2.10
April, 1916	1.95– 2.00
July, 1916	2.25– 2.75
October, 1916	2.25– 2.75
January, 1917	2.50– 3.25
April, 1917	2.35– 2.85
July, 1917	2.40– 3.40
October, 1917	2.40– 2.60
January, 1918	2.15– 2.25
April, 1918	$1.75–$1.80
July, 1918	1.75– 1.80
October, 1918	1.75– 1.80
January, 1919	1.75– 2.00
April, 1919	1.75– 2.00
July, 1919	2.00– 2.25
October, 1919	2.25– 2.35
January, 1920	3.75– 4.00
April, 1920	7.00– 7.50
July, 1920	7.75– 8.00
October, 1920	5.75– 6.00

*From *Oil, Paint, and Drug Reporter.*

ORANGE, WEST INDIAN—PRICES PER POUND*

August, 1914	$2.05–$2.10	January, 1918	$2.00–$2.10
January, 1915	1.50– 1.60	April, 1918	1.80– 1.90
April, 1915	1.25– 1.35	July, 1918	1.80– 1.90
July, 1915	1.50– 1.60	October, 1918	1.75– 1.80
October, 1915	1.70– 1.75	January, 1919	1.75– 1.80
January, 1916	1.50– 1.60	April, 1919	1.75– 1.80
April, 1916	1.75– 1.80	July, 1919	1.90– 2.00
July, 1916	2.50– 2.75	October, 1919	2.35– 2.40
October, 1916	2.75– 2.80	January, 1920	4.00– 4.25
January, 1917	2.25– 2.35	April, 1920	7.50– 7.75
April, 1917	2.35– 2.45	July, 1920	9.00– 9.25
July, 1917	2.67– 2.75	October, 1920	6.00– 6.25
October, 1917	2.30– 2.45		

*From *Oil, Paint, and Drug Reporter.*

BERGAMOT—PRICES PER POUND*

August, 1914	$5.00–$5.25	January, 1918	$6.00–$6.20
January, 1915	3.75	April, 1918	5.50– 6.00
April, 1915	3.00– 3.15	July, 1918	5.60– 5.75
July, 1915	3.15– 3.50	October, 1918	7.50– 8.00
October, 1915	3.15– 3.50	January, 1919	7.00– 7.50
January, 1916	3.50	April, 1919	6.40– 6.50
April, 1916	3.30– 3.50	July, 1919	5.15– 5.50
July, 1916	3.70– 3.75	October, 1919	4.75– 5.00
October, 1916	5.50– 5.75	January, 1920	5.00– 5.25
January, 1917	6.25– 6.50	April, 1920	7.50– 7.75
April, 1917	5.75– 6.00	July, 1920	6.75– 7.00
July, 1917	6.00– 6.25	October, 1920	6.25– 6.50
October, 1917	6.00– 6.20		

*From *Oil, Paint, and Drug Reporter.*

CEDRAT OIL—IMPORTS FOR CONSUMPTION—REVENUE

Fiscal Year	Rates of Duty	Quantity (lb.)	Value	Duty Collected	Value per Unit of Quantity	Actual and Computed Ad Valorem Rate (Per Cent)
1908	Free	47	$ 263	.....	$5.60	.....
1909	Free	297	950	.....	3.20	.....
1910	Free	210	612	.....	2.91	.....
1911	Free	129	955	.....	7.40	.....
1912	Free	424	1,329	.....	3.13	.....
1913	Free	115	555	.....	4.83	.....
1914	Free	86	415	.....	4.83	.....
1914	20 per cent	73	355	$71	4.86	20.00
1915	20 per cent	788	3,721	744	4.72	20 00
1916	20 per cent	438	1,966	393	4.48	20.00
1918	20 per cent	200	158	31	.79	20.00
1919	20 per cent	336	531	106	1.57	20.00

OIL OF BERGAMOT—PRICES PER POUND*

Quarters, 1913:†	
First	$6.43
Second	6.00
Third	5.70
Fourth	6.13
Quarters, 1914:†	
First	6.03
Second	5.48
Third	5.53
Fourth	4.75
Quarters, 1915:†	
First	3.38
Second	3.08
Third	3.13
Fourth	3.25
Quarters, 1916:†	
First	3.41
Second	3.61
Third	4.35
Fourth	5.41
Quarters, 1917:†	
First	$6.00
Second	5.91
Third	6.00
Fourth	6.00
Quarters, 1918:†	
First	5.66
Second	5.50
Third	5.78
Fourth	7.3 3
Quarters, 1919:‡	
First	6.90
Second	6.40
Third	5.15
Fourth	4.5 0
Quarters, 1920:‡	
First	5.00
Second	7.50
Third	6.75
Fourth	6.25

*From *War Industries Board Bulletin No. 50* and *Oil, Paint, and Drug Reporter.*
†Quarterly prices or average monthly prices from *Oil, Paint, and Drug Reporter.*
‡Low, first Monday in each month, from *Oil, Paint, and Drug Reporter.*

OIL OF LEMON—PRICES. DOLLARS PER POUND*

Quarters, 1913:†	
First	$2.70
Second	3.33
Third	4.46
Fourth	3.55
Quarters, 1914:†	
First	2.73
Second	2.15
Third	2.16
Fourth	1.53
Quarters, 1915:†	
First	1.11
Second	1.05
Third	1.11
Fourth	1.01
Quarters, 1916:†	
First	1.00
Second	.95
Third	.91
Fourth	1.01
Quarters, 1917:†	
First	$1.18
Second	1.13
Third	1.11
Fourth	1.06
Quarters, 1918:†	
First	.98
Second	1.13
Third	1.08
Fourth	1.43
Quarters, 1919:‡	
First	1.60
Second	1.20
Third	1.15
Fourth	1.15
Quarters, 1920:‡	
First	—1.45
Second	2.00
Third	—1.65
Fourth	1.15

*From *War Indutries Board Bulletin No. 50* and *Oil, Paint, and Drug Reporter*
†Quarterly prices, or average of monthly prices from *Oil, Paint, and Drug Reporter.*
‡Low, first Monday in each month, from *Oil, Paint, and Drug Reporter.*

BERGAMOT OIL—IMPORTS FOR CONSUMPTION—REVENUE

Fiscal Year	Rate of Duty	Quantity (lb.)	Value	Duty Collected	Value per Unit of Quantity	Actual and Computed Ad Valorem Rate (Per Cent)
1908	Free	94,967	$284,173	.....	$2.99	.....
1909	Free	89,957	281,211	.....	3.13	.....
1910	Free	38,155	133,490	.....	3.49	.....
1911	Free	65,199	222,225	.....	3.41	.....
1912	Free	67,526	315,227	.....	4.67	.....
1913	Free	64,259	310,835	.....	4.84	.....
1914	Free	11,494	33,301	.....	2.90	.....
1914	20 per cent	25,153	105,329	$21,065	4.19	20.00
1915	20 per cent	56,781	150,062	30,012	2.95	20.00
1916	20 per cent	69,440	178,300	35,660	2.56	20.00
1917	20 per cent	50,634	179,182	35,836	3.55	20.00
1918	20 per cent	57,689	241,465	48,293	4.18	20.00
1919	20 per cent	41,262	185,318	37,064	4.50	20.00

OIL OF LIMES—IMPORTS FOR CONSUMPTION—REVENUE

Fiscal Year	Rate of Duty	Quantity (lb.)	Value	Duty Collected	Value per Unit of Quantity	Actual and Computed Ad Valorem Rate (Per Cent)
1908	Free	6,765	$4,976	.....	$0.74	.....
1909	Free	21,991	9,973	.....	.45	.....
1910	Free	8,025	9,137	.....	1.14	.....
1911	Free	9,122	9,466	.....	1.04	.....
1912	Free	12,821	9,165	.....	.71	.....
1913	Free	13,075	15,025	.....	1.15	.....
1914	Free	4,725	7,643	.....	1.62	.....
1914	20 per cent	11,834	16,185	$3,237	1.37	20.00
1915	20 per cent	9,154	9,279	1,855	1.01	20.00
1916	20 per cent	19,765	29,694	5,938	1.50	20.00
1917	20 per cent	26,551	49,001	9,800	1.84	20.00
1918	20 per cent	29,137	73,685	14,737	2.52	20.00
1919	20 per cent	16,272	24,273	4,847	1.49	20.00

NEROLI-SYNTHETIC AND OIL OF NEROLI, PETALE—PRICES, DOLLARS PER POUND*

Neroli, Synthetic:	
April, 1916	$18.00–$20.00
July, 1916	18.00– 20.00
October, 1916	18.00– 20.00
January, 1917	18.00– 20.00
April, 1917	18.00– 20.00
July, 1917	18.00– 20.00
October, 1917	18.00– 24.00
January, 1918	18.00– 24.00
April, 1918	18.50– 25.00
July, 1918	18.50– 24.00
October, 1918	18.50– 24.00
January, 1919	20.00– 30.00
April, 1919	18.50
July, 1919	18.50
October, 1919	14.00– 15.00
January, 1920	14.00– 15.00
April, 1920	14.00– 15.00
July, 1920	14.00– 15.00
October, 1920	14.00– 16.00
Oil of Neroli, Petale:	
January, 1913	$45.00
April, 1913	45.00
July, 1913	45.00
October, 1913	45.00
January, 1914	45.00
Oil of Neroli, Petale—*Continued:*	
April, 1914	$45.00
July, 1914	51.00
October, 1914	60.00
January, 1915	53.33
April, 1915	50.00
July, 1915	46.66
October, 1915	45.00
January, 1916	45.00
April, 1916	45.00
July, 1916	45.00
October, 1916	45.00
January, 1917	45.00
April, 1917	50.00
July, 1917	63.33
October, 1917	83.33
January, 1918	80.00
April, 1918	80.00
July, 1918	80.00
October, 1918	90.00
April, 1919	120.00
July, 1919	130.00
October, 1919	130.00
January, 1920	130.00
April, 1920	130.00
July, 1920	130.00
October, 1920	†

*From *Oil, Paint, and Drug Reporter* and *War Industries Board Bulletin No. 50*
†Nominal.

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